WATER QUALITY

Estuarine Processes

The water quality of the Elizabeth River, as assessed by conventional parameters, nutrients, and toxic compounds, is affected by several important factors. Among these factors are the physiographic and hydrologic character of the River which control the relative effects of pollutants which are discharged into the River.

The Elizabeth has been extensively modified due to dredging. Dredging of the relatively shallow estuary was necessary to allow commercial, military, and recreational use of the River. Channels, which vary between 20 and 45 feet, are maintained throughout the Mainstem and much of the Southern Branch. Many sections of the Southern Branch are dredged bank to bank to allow berthing of large commercial and military ships. Navigation channels are also maintained in the Lafayette River and the Eastern and Western Branches. The ACOE is in the preliminary phases of deepening the outbound channel from Lamberts Point to the Hampton Roads Harbor from its current depth of 45 feet to 55 feet. Deepening the outbound channel will allow the large coal colliers to load full loads at the Lamberts Point Terminal. Presently, these vessels only partially fill at Lamberts Point and top off their load elsewhere.

The Mainstem and Southern Branch are part of the Intercoastal Waterway which connects the Chesapeake Bay with the Albemarle Sound in North Carolina. Two inland routes connect the Southern Branch with the Sound. The Chesapeake and Albemarle Canal connects with the Elizabeth at the ACOE locks in Great Bridge. Neilson and Sturm (1978) concluded that the freshwater input from the canal is negligible. The other Intercoastal route, via the Dismal Swamp Canal, represents the only measured freshwater flow into the Elizabeth. Neilson (1975) reported a long term yearly average flow of 77 MGD. The flow, representing drainage from the Dismal Swamp and Lake Drummond, is controlled by the ACOE locks and spillway located at Deep Creek. For most of the year the flow is via the spillway, but during late summer and early fall, flow is controlled by the locks.

The only other significant inputs of freshwater are through runoff and effluent discharges. The slight topographic relief (typical of the Coastal Plain), small drainage area, and high degree of urbanization in the basin result in a reduced base ground water flow into the Elizabeth and an increase in magnitude of the peak flows during storm events. This results in relatively higher nonpoint source loading than would otherwise be expected.

Effluent discharges are the other major source of freshwater. The major STP's contribute an average of 55 MG of freshwater to the Elizabeth River each day.

The salinity within the Elizabeth ranges from 10 to 25 ppt, with the highest salinities near the mouth, particularly in the dredged channel where the heavier saltwater intrusion flows near the bottom. Although tidal currents are weak (~0.5 knots), other factors, such as wind induced currents, result in a well-mixed and nearly homogenous condition through much of the system. Due to these conditions, the flushing capability of the Elizabeth declines with increasing distance from the River's mouth. Neilson (1975) estimated that it would take up to 40 days to eliminate 90 percent of a conservative substance injected into the upper reaches of the Southern Branch.

In summary, the Elizabeth is ill-suited to assimilate and disperse the pollutants which enter through numerous sources located throughout the system. Therefore, the introduction of pollutants must be reduced or eliminated to improve the environmental quality of the Elizabeth.

Ambient Water Quality

Ambient water quality, for the purpose of this review, will be considered as the assessment of "instream" water quality. Typically, ambient water quality can be assessed by either chemical or biological parameters or a combination of these parameters. Also, water quality can be assessed by comparing water quality parameters with those of a similar type water body or by comparing water parameters with water quality standards and criteria. Water quality standards and criteria are specific numerical values which are developed to maintain or enhance ambient water quality. Water quality can be affected by sediment quality because they are interrelated with complex chemical and physical processes controlling the exchange between the sediment-water interface. The sediment quality of the Elizabeth River will be considered in a separate section.

The SWCB summarized the existing ambient water quality data for the Elizabeth River in their 1983 report, "The Elizabeth River: An Environmental Perspective." The report analyzed data collected under several different programs or special studies conducted during the period from 1965 to 1981. The water quality data analyzed included dissolved oxygen, pH, species of nitrogen and phosphorus, and five heavy metals. Information concerning toxic organic compounds was not available. Ambient monitoring stations located in the Elizabeth River were reduced to only three stations in the early 1980's. One station each is located in the Eastern and Southern Branches, and one station is located at the entrance to the channel of the Lafayette River. The Chesapeake Bay Monitoring Program has one station located near the entrance of the Elizabeth (Red Buoy 18) and has collected water quality data since 1984.

The Hampton Roads Water Quality Agency, under contract to the State Water Control Board, summarized the existing water quality information for conventional pollutants, heavy metals, and toxic materials in 1986 (HRWQA, 1986). The following excerpt is HRWQA's assessment of water quality in the Elizabeth River:

> <u>Conventional Pollutants</u>
> Traditionally, for the purposes of this report, the parameters falling into this category are dissolved oxygen (DO), biochemical oxygen demand (BOD), fecal coliform bacteria, chlorophyll "a" as an indicator of nutrient enrichment, and various species of nitrogen and phosphorus.
>
> Water quality conditions for these parameters in the mid-1970s exhibited fairly consistent locational trends. The closer to the mouth, the better the conditions. Dissolved oxygen levels ranged from good near the mouth to poor in the upper reaches of the Southern Branch and the Eastern Branch. Strong diurnal variation also was observed in the upper reach of the Southern branch. D.O. levels below 4 mg/l were common at all stations on the Southern and Eastern branches. The only areas exhibiting concentrations consistently above 4 mg/l and average values above 5 mg/l were the Western Branch and the Lafayette River. Also, generally speaking, surface values were better than values observed in the deeper waters. Summarily, dissolved oxygen levels over the last decade were marginal in most areas. However, there is no indication of serious and continuous oxygen depletion and D.O. level trends have been improving.
>
> BOD levels were found to be elevated above typical values for other estuaries in the area throughout the system. Of the range of values observed in the system, the lower values were usually in the deeper areas.
>
> Total nitrogen and total phosphorus concentrations were greatest in the upstream areas and least near the mouth. Algal blooms were observed in the upper reach of the Southern branch, however observations of chlorophyll "a" throughout the rest of the system ranged from 10 mg/l - 20 mg/l which is not considered to be near the level necessary to cause algal blooms in estuarine environments.
>
> Fecal coliform counts were universally high. No areas exhibited levels conducive to collection of oysters for direct marketing.
>
> The 1986 SWCB 305(b) report, the latest compilation of water quality information for the Elizabeth River refers to the report prepared in 1983 by the SWCB and the HRWQA entitled, "Background and Problem Assessment Report for the Elizabeth River" as the source for recent water quality information. That report concludes that dissolved oxygen and nutrient levels are generally within acceptable ranges with some exceptions. The Southern branch continues to exhibit the highest percent of observations falling below the average standard of 5 mg/l. Nitrogen has not shown any discernible trend in any of the branches. Phosphorus showed a significant decrease over time in the Main, Southern and Western Branches. No data for fecal coliform bacteria is cited as having been collected more recently than the mid-1970 information although individual researchers have undoubtedly done so. It is presumed that levels are still too high to allow direct marketing of harvested oysters and that the State Health Department would not authorize their taking in any event because of the volume of vessel traffic and marine activity.
>
> The Chesapeake Bay Study final report cites the HRWQA data and modeling as its

source of information for conventional pollutants and apparently concurs in its conclusions regarding water quality conditions.

From the above summary of trends in conventional pollutant levels the following conclusions may be drawn as stimuli to the development of preliminary management recommendations. Dissolved oxygen levels appear to be stabilized at levels near the state standards, however, very little additional capacity for accepting oxygen demanding substances in the river system is available. Although the above referenced report does not specifically address BOD it is assumed to have remained the same or been reduced by virtue of the fact that the POTW's discharging to the system have been upgraded, no significant new dischargers to the system have come on line since the completion of the mid-1970 studies, and because dissolved oxygen levels have shown a stabilizing trend. With regard to nutrients, phosphorus concentrations are moderately high but this has not generally resulted in excessive algal densities. Some attribute this to low nitrogen concentrations and others to light limitations. Since the fecal coliform bacteria levels have been excessive since the early 1900s and since all POTW's and private treatment plant dischargers to the system disinfect, and since the Lamberts Point and Pinners Point POTWs will be combined and disinfection further enhanced, any additional management strategies for this parameter will have to focus on transient, intermittent and nonpoint sources of the parameter.

Metals and Toxics

For many years the HRWQA and others have speculated that the most important water quality problems in the Elizabeth River were related to heavy metals and various other anthropogenically introduced toxic materials. The Hampton Roads Water Quality Management Plan, by direction of the EPA, did not include water quality sampling, testing or modelling for these materials. Fortunately, subsequent to that planning program the SWCB, EPA Chesapeake Bay Program and others have collected water column and sediment data for many metals and toxics of concern. While much remains to be done in scientific research (particularly in the area of determining the relative magnitude of soluble versus particulate metals), the setting of stream standards, and determination of discharge limits for these and other materials, the information available is useful in identifying and targeting preliminary management recommendations.

Data reported by the SWCB, the EPA Chesapeake Bay Program and the research institutions indicate concentrations of heavy metals in the water column which exceed the 1980 (and 1985 revisions) EPA chronic toxicity criteria or approach acute toxicity levels for saltwater aquatic life and may be of concern if biologically significant levels of the soluble fractions are present. Specific information on various parameters follows and although not always stated the reported concentrations are the mean observations within each of the various branches, according to the SWCB.

Arsenic concentration levels are found in all branches of the system. Observed values are in the 2-3 ug/l range compared to EPA chronic toxicity criteria levels of 63 ug/l. The acute toxicity criteria is 120 ug/l. Thus, arsenic does not appear to pose a problem.

Cadmium concentrations are similar throughout the system with concentrations ranging from 8-14 ug/l compared to the EPA chronic toxicity criteria of 9.3 ug/l. The acute toxicity criteria is 43 ug/l. Cadmium appears to be a metal of concern for management action.

Chromium concentrations observed range from 11-15 ug/l. The EPA chronic toxicity criteria is 18 ug/l and the acute toxicity criteria is 54 ug/l. Chromium does not appear to pose a problem.

Copper concentrations detected in the system over the past decade range from 17-21 ug/l compared to the EPA acute toxicity level of 2.9 ug/l. No chronic toxicity level is listed in the Federal Register. This is a parameter of concern.

Lead concentrations in the system range from 12-20 ug/l consistently throughout the system. The EPA chronic toxicity criteria is 5.6 ug/l. The acute toxicity criteria is 140 ug/l. Lead appears to be of concern at this time.

Mercury concentrations are greatest in the Main stem with the mean level at 9.7 ug/l while the other branches have mean concentrations of .4-.5 ug/l. The EPA chronic toxicity criteria is .025 ug/l. The acute toxicity criteria is 2.1 ug/l. At least in the main stem, this is of much concern.

Nickel concentrations range from 105-117 ug/l. The EPA chronic toxicity criteria is 7.1 ug/l and the acute toxicity criteria is 140 ug/l. Nickel is of concern.

Zinc levels are in the range of 62-69 ug/l in the Western and Eastern branches with lesser concentrations of 35-40 ug/l in the other branches. The EPA chronic toxicity criteria is 58 ug/l. The acute toxicity criteria is 170 ug/l. This indicates that zinc levels are somewhat elevated.

Caution must be exercised in comparing metal levels in the water column to the water quality criteria. The July 29, 1985 Federal Register from which the acute and chronic toxicity criteria were taken includes the following proviso regarding their reliability;

> "EPA believes that a measurement such as 'acid-soluble' would provide a more scientifically correct basis upon which to establish criteria for metals. The criteria were developed on this basis. However, at this time, no EPA approved methods for such a measurement are available to implement the criteria through the regulatory programs of the Agency and the States. The Agency is considering development and approval of methods for a measurement such as acid-soluble. Until available, however, EPA recommends applying the criteria using the total recoverable method. This has two impacts: (1) Certain species of some metals cannot be analyzed directly because the total recoverable method cannot distinguish between individual oxidation states, and (2) these criteria may be overly protective when based on the total recoverable method."

It is uncertain whether the historical metal data reported by the SWCB was total, total recoverable, or soluble, however most historical metal data was usually in the form of total or total recoverable. The form of the metal becomes important when comparing the observed data with EPA's criteria because most metals are usually associated with the suspended particulates in the water column and are, therefore, generally considered to be far less toxic. Thus, strict comparisons of historical data with EPA's acid soluble criteria can lead to overestimating the potential for toxicity.

The Applied Marine Research Laboratory (AMRL) of Old Dominion University investigated the effects of land use activities on water quality in the Elizabeth River in their 1988 report to the SWCB entitled "An Evaluation of the Distribution of Toxicants/ Mutagens in the Elizabeth River, Virginia in Relation to Land Use Activities." During the first phase of the study, the AMRL screened over 50 sites on the River for relative biological activity (i.e. toxicity, mutagenticity). Based on these results, the AMRL evaluated water samples, chemically and biologically, at 15 ambient sites (mid-channel every river mile) and 12 land use sites (receiving stream water near the selected site). The following excerpt is a summary of water quality conditions noted during this phase of the study:

> The water quality conditions of the Elizabeth River during the Phase II collections were poorer than the range of conditions observed in the lower Chesapeake Bay over the past several years. However, conditions have appeared to improve for most parameters when compared to Elizabeth River water quality data from the 1970's. The following are summary points concerning the water quality conditions durjng Phase II:
>
> a) Ammonia concentrations were greatest at ambient sites in the Southern Branch. In fact, ammonia concentrations were greater at the mid-channel ambient sites than at proximate LUA sites, suggesting that release from contaminated anoxic sediments in the deep channels is a major source of ammonia to the systems.
>
> b) The TKN concentrations displayed similar patterns to that of ammonia (i.e. higher concentrations for ambient sites in the Southern Branch) except that levels were also somewhat higher at four LUA sites: Colonna's, NORSHIPCO-Brambleton, Atlantic Wood, and Lake Kingman-Virginia Chemical, Inc.
>
> c) The nitrite-nitrate concentrations were elevated at certain LUA sites: Milldam Creek (urban runoff area that was former site of Chilean Nitrate prior to its loss to fire), Virginia Power canal dike, Swan Oil, Royster, Colonna's and NORSHIPCO-Berkley. The nitrate concentrations at the ambient sites were lower than proximate LUA sites, suggesting that levels were diluted/dissipated in the waters of the ambient sites.
>
> d) The total phosphorus (TP) patterns were generally similar to those observed for ammonia: higher concentrations in samples taken from mid-channel ambient sites than found in proximate LUA sites. The exceptions were Atlantic Wood and Haven Creek, which displayed the highest levels of TP. Except for these sites, sediment release appears to be a likely source of phosphorus to the system.
>
> e) The total suspended solids (TSS) concentrations observed during the Phase II studies were generally within the range observed for the Chesapeake Bay. The two sites displaying the greatest TSS levels were Atlantic Wood and Lake Kingman-Virginia Chemical, Inc. It is believed that the TSS concentrations at the former site were due to high levels of oil and grease, and those at the latter site were due to construction activities in the vicinity at the time of the collections.
>
> f) The indications of sediment release of ammonia and phosphorus to the water column suggest that management and control strategies must be designed with this sort of indirect and diffuse source in mind.

The concentrations of heavy metals generally were lower during the Phase II investigations than those reported for the 1970's. However, several metals remained elevated above criteria established for the protection of marine life.

a) Cadmium (Cd) concentrations were below detection limits for most sites. The samples taken from Swan Oil and the ambient site (MS5) at the confluence of the Southern Branch displayed the highest Cd concentrations, but even these levels were below the criterion for the protection of marine life.

b) The arsenic (As) and chromium (Cr) concentrations were near to their detection limits for all sites, with no apparent spatial patterns.

c) Overall concentrations of copper (Cu) in Phase II samples tended to be lower than those observed in the 1970's. Nonetheless, the criterion for the protection of marine life was exceeded at a number of sites: in particular, Atlantic Wood, Swan Oil, Scott Creek, Lake Kingman- Virginia Chemical, Inc., Royster, and Haven Creek.

d) Lead (Pb) levels in the waters of the Elizabeth River appeared to have decreased substantially over the past 15 years. Atlantic Wood, the Western Branch ambient sites and sites near the confluence of the Southern Branch with the Mainstem had the highest levels, but even these were below the chronic criterion for the protection of marine life.

e) Nickel (Ni) concentrations in the waters of the Elizabeth River have appeared to have decreased over the past 15 years. However, all levels observed in Phase II were above the chronic criterion for the protection of marine life. Concentrations at ambient sites tended to be lower than proximate LUA sites.

f) Although zinc (Zn) concentrations for all sites were within the range of values reported for the 1970's, they were considerably above the previously reported means, as well as the chronic criterion for the protection of marine life. Zinc appears to be a ubiquitous contaminant of concern in the Elizabeth River. However, this metal may not be in its biologically-active form, so the full potential for ecological effects may not be realized.

A large number of organic compounds were observed in the Phase II samples. However, most of the compounds were found in low concentrations (ng/l to low ug/l range), below the detection limits of standard analytical techniques. Therefore, future studies should include large sample volumes (as used in Phase II) or should employ concentration techniques (as used in Phase I) in order to trace biologically-active organic contaminants.

a) A total of 24 of the EPA "priority pollutants" were observed in the Phase II samples. One or more of the "priority pollutants" were detected at 23 of the 27 Phase II sites. The four sites (MS3, WB1, WB2, and Lake Kingman-Virginia Chemical, Inc.) with samples containing no detectable "priority pollutants" were all located within the same geographic region at the confluence of the Western Branch with the Mainstem. These sites displayed the lowest levels of all organic contaminants.

b) The major groups of organic contaminants in the Elizabeth River were alkanes, alkyl-benzenes, polynuclear aromatic hydrocarbons, propanoic acids, solvents (e.g. tetrachloroethane, dichlorobenzene, butoxyphosphate-ethanol, etc.), tribromomethane and phthalates.

c) Most of the sites were similar in overall patterns of organic constituents except for Atlantic Wood, an ambient site in the Elizabeth River (EB2) and an ambient site in the Southern Branch (SB6) which displayed higher concentrations of organic contaminants. Samples from these sites contained a number of alkanes, alkylated aromatics, and propanoic acids, probably associated with fossil fuels (e.g. creosote fractions for Atlantic Wood, possibly oil spills for the ambient sites). The sample from the Mainstem ambient site MS1 differed from the others due to the presence of a relatively high concentration of an unknown volatile chemical.

d) Relationships between organic constituents and biological effects of samples were weak, if present at all.

The sites with the highest quantitative rankings for water chemistry data were Atlantic Wood (by far the highest for all ranking categories), the ambient site SB6 (primarily due to organics), Swan Oil (Metals), and the ambient site EB2 (organics and metals).

Results of toxicity tests from this study are presented in following sections.

Point Source Assessment

Ambient water quality reflects the inputs of pollutants into the system from various sources. Pollutants have been categorized as originating from either point sources or nonpoint sources. Point source discharges have become synonymous with NPDES discharges, although not all point source discharges are regulated by the NPDES program (i.e. stormwater discharges). For the purposes of this report, point source discharges of pollutants will be considered as NPDES discharges. Although stormwater has been defined as a point source discharge, it is more effectively managed through nonpoint sources controls and will be considered in the nonpoint source assessment section.

As of March 1988, there were 61 facilities with NPDES permits which discharge to the Elizabeth River (Table 3). Of these 61 facilities, nine are majors and 52 are minor facilities. Major facilities are those which through a memorandum of understanding between the SWCB and EPA are designated as such. Criteria for designating a major may include flow, nature of the discharge, or other factors which would warrant inclusion on the majors list. The status of a facility may change between major and minor as deemed necessary by the SWCB and/or the EPA.

The eight major dischargers on the River include 2 federal, 3 municipal, and 3 industrial facilities. Of the 52 minor facilities, 44 are industrial, 10 are municipal, and one is a federal facility.

As discussed earlier, the NPDES requires facilities to meet certain permit requirements, including specific effluent limits, BMPs, and proper reporting of permit compliance. The aggressive enforcement and compliance program initiated by the SWCB in the spring of 1987 results in Notices of Violation for owners/operators of facilities which fail to meet the requirements of the permit. Those facilities which are in significant non-compliance are referred to the SWCB enforcement section for administrative or legal actions.

A review of NOVs issued to Elizabeth River facilities for the period from November, 1987 to April, 1988 indicates an average of eight facilities receive NOVs each month. The Notices are typically the result of permit violations for conventional parameters (i.e. TSS, pH, and Oil/Grease), and improper, late, or nonsubmittal of compliance reports. Occasionally, violations for toxic compounds (usually heavy metals), noncompliance with BMPs or WPCCs, or spills/illegal discharges result in the issuance of NOVs.

A major concern in the Elizabeth River is the discharge of toxic substances into the River. The NOV program does not currently consider all reported toxics data in its compliance auditing for several reasons, but the toxic nature of effluents and receiving waters have been characterized through several other programs. These include the Toxics Management Programs required in NPDES permits for selected discharges, the SWCB's effluent characterization and toxicity assessment programs, and numerous reports resulting from research activities in the River.

Toxicity:Point Sources and Receiving Waters

In 1987, the SWCB supported a study by Old Dominion University's Applied Marine Research Laboratory (AMRL) to evaluate the distribution of toxins in the Elizabeth River. In the first phase of their study, the AMRL evaluated the relative biological effects (using a variety of biological tests) at over 50 land use activities (LUAs) located through the system. Based on the results of the first phase, 12 LUAs were selected for further evaluation (Biological tests include - fish embryo; AMES; Cytotoxicity) as well as 15 ambient (mid-channel) stations located throughout the system. The following is a summary of biological effects noted during each phase:

The following represents a summary of Phase I findings, emphasizing top ranked LUA sites (general LUA categories in parentheses):

a) The sites that were ranked highest for overall biological effects were Haven Creek (urban runoff), NORSHIPCO-Brambleton (shipyard), and Atlantic Wood (chemical processing/wood treatment); followed by a second tier of rankings including two chemical processing sites (Smith-Douglass and Virginia Chemical, Inc.-Lake Kingman), two marina-dock areas (Scott Creek and Portside), and a shipyard (Colonna's).

b) The top ranked LUA sites for mutagenic activity were Haven Creek (urban runoff), the Ford Plant (industrial and commercial), Atlantic Wood (chemical processing), NORSHIPCO-Brambleton (shipyard), and Indian River Creek (urban runoff).

c) The highest ranked sites for effects in the bacterial respiration assay were Portside (marinas and docks; 57% depression), Milldam Creek (urban runoff; 51% depression), NORSHIPCO-Brambleton (shipyard; 44% depression), Haven Creek (urban runoff; 41% depression), and Tropicana (oil terminal; 37% depression).

d) The highest ranked LUA sites for acute mortality (within 48-hrs) in fish embryos were Swan Oil (oil terminal; 79% mortality), Scott Creek (marinas and docks; 57% mortality), Lake Kingman-Virginia Chemical, Inc. (chemical processing; 50% mortality), and Virginia Power dike area (43% mortality).

e) The highest ranked LUA sites for "chronic" mortalities occurring between days 3 and 21 of the fish embryo assays were Lambert's Point STP (POTW; 75% mortality), Exxon Oil (oil terminal; 39% mortality), Milldam Creek (urban runoff; 38% mortality), Norfolk International Terminals (industrial and commercial; 34% mortality), and the Army Base STP (POTW; 31% mortality).

f) The highest ranked LUA sites for sublethal effects (undeveloped embroys, unhatched eggs, deformities) were Cargill (chemical processing; 61% affected), Gilligan Creek (urban runoff; 61% affected), Lambert's Point Landfill (landfills and disposal areas; 52% affected), N&W railroad bridge (industrial and commercial; 42% affected), Indian River Creek (urban runoff; 42% affected), and Atlantic Wood (chemical processing; 36% affected). It is interesting to note that three of the sites (Cargill, Gilligan Creek, and N&W railroad bridge) were in close proximity to each other, suggesting a geographic linkage to a common source of contaminant(s) producing the sublethal development effects in the fish embryos.

g) In the fish embryo assays, acute mortality, "chronic" mortality, and sublethal effects are mutually exclusive responses which may produce an additive effect on the overall survival of a population. For example, the results of the Medaka assays for the sample taken in the vicinity of Huntsman Chemical (chemical processing) indicated moderate levels of (and rankings for) acute mortality, "chronic" mortality and sublethal effects, but the cumulative effect was that nearly 80% of the test population was adversely affected. The LUA sites producing the greatest cumulative effects in the fish embryo assays were Swan Oil (oil terminal; 85% affected), Gilligan Creek (urban runoff; 83% affected), Lambert's Point STP (POTW; 80% affected), Lake Kingman-Virginia Chemical, Inc. (chemical processing; 78% affected); and Huntsman Chemical (chemical processing; 77% affected).

6. Although the Phase II assays did not produce the same degree of biological effects as observed for the Phase I investigations, distinct spatial patterns were discernible:

a) The "ambient" sites tended to be associated with less severe biological effects than proximate LUA sites.

b) The only sites to display mutagenic activity were three "ambient" sites from the Mainstem of the Elizabeth River (Sites MS2, MS4, and MS5) and LUA site in proximity to the Virginia Power canal dike. The levels of mutagenic activity were considerably below those observed for Phase I assays.

c) The sites producing the greatest effects in the cytotoxicity assays of human cell cultures were some of the same ambient sites in the Mainstem (MS4 and MS5), Lake Kingman-Virginia Chemical, Inc., NORSHIPCO-Brambleton, and Scott Creek (marinas and docks).

d) The sites producing more than 10% acute mortality in the Phase II fish embryo assays were NORSHIPCO-Brambleton (93% mortality), Haven Creek (13% mortality), and Virginia Power canal dike area (13% mortality).

e) Only two ambient Mainstem sites produced more than 20% "chronic" mortality in the fish embryo assays: MS1 (20%), and MS4 (27%).

f) Sublethal effects on fish embryos were the most striking biological effects observed in Phase II investigations. Six sites had water extracts which produced sublethal effects (undeveloped/unhatched eggs, or deformities) in more than 50% of the test populations: Virginia Power canal dike (87% affected), Royster (chemical processing; 73% affected), the proximate ambient site (60% affected), Milldam Creek (60% affected), Atlantic Wood (53% affected), and Swan Oil (53% affected). Undeveloped/unhatched eggs were the most common sublethal effects, but deformities from scoliosis to two-headed embryos were observed.

g) Cumulative effects (acute, "chronic", and sublethal effects) on fish embryos were observed to exceed 50% of the test populations for six sites: NORSHIPCO-Brambleton (100% affected), Virginia Power canal dike (100% affected), Royster (73% affected), two ambient sites (MS1 and SB2; 73% and 67% affected, respectively), Swan Oil (67% affected), Milldam Creek (60% affected), and Atlantic Wood (53% affected).

Since August of 1987, The SWCB's mobile laboratory has been stationed in the Elizabeth Basin and staff members have concluded several toxicity assessments. These assessments have included biological and chemical characterization of effluents from several facilities on the River, as well as characterization of receiving waters near each facility. These tests have documented acute toxicity for several outfalls and chronic toxicity in the receiving stream (Banks and Kuhn, 1988; Banks and Richards, 1988; Banks and Roller, 1988). These studies noted significant toxicity and high concentrations of toxic compounds for discharges from floating drydocks and oil/water separators at area shipyards. These studies have resulted in several TREs and additional studies to develop toxicity control plans for these discharges. It is anticipated that the laboratory will continue to perform toxicity assessments in the Basin for several years.

Nonpoint Source Assessment

Nonpoint source pollution is usually designated as pollution which is not discharged through a discrete pipe or other conveyance. Nonpoint source pollution is often diffuse in nature and is difficult to define or control. Making a connection between nonpoint sources and water quality degradation is difficult or in some instances impossible.

Most nonpoint sources are land-based, such as agricultural and urban runoff, though water-based sources, such as marinas, docks, and wet-slips are of concern in the Elizabeth River and elsewhere. Vessel traffic, both commercial and recreational, are transient sources of water-based nonpoint pollution. Significant sources of nonpoint pollution in the Elizabeth River have been identified as;

- -Urban runoff
  - Commercial/institutional
  - Industrial
  - Residential
  - Federal facilities
- -Vacant land/Agricultural runoff
- -Marinas and docks
- -Marine railways, Wetslips, and Drydocks
- -Commercial and Recreational Vessels
- -Highways
- -Land Development/Construction Activities
- -Landfills/Hazardous Waste Sites
- -Port related commerce (i. e. coal loading facilities)
- -Raw sewer overflows

Stormwater is the primary vehicle by which pollutants from nonpoint sources are carried to the Elizabeth River. Although stormwater has been designated as a point source discharge (49 CFR 37998), it is considered more effective to control stormwater with nonpoint source controls. Direct discharge from water-based sources and atmospheric deposition are also pathways by which pollutants enter the Elizabeth River. For example, Tributyltin (TBT), an organometallic compound which is extremely toxic to aquatic organisms, is commonly used as an antifouling paint on boats. TBT leaches out of the paint on the ship's hull, thus preventing the attachment of fouling organisms. Recent research in areas with heavy recreational and commercial boat traffic implicate TBT as being responsible for adversely affecting aquatic organisms.

Several studies, such as the National Urban Runoff Program (NURP, 1983), have identified pollutants in stormwater that originate from various nonpoint sources. Sediments, nutrients, pathogens, toxic substances, and other pollutants are transported by stormwater to receiving waters, such as the Elizabeth River. Storm runoff from urban areas has been compared, qualitatively, to sewage effluent after secondary treatment, but the volume discharged can be much greater than the discharge from even large POTWs.

Limited information exists concerning the effects of specific land use activities in the Elizabeth River Basin on water quality, but the Hampton Roads Water Quality Management Plan (Regional 208 plan) concluded that a significant portion of the Elizabeth River's water quality problems are a result of nonpoint source pollution. In fact, the 1978 HRWQMP concluded that if all point source discharges were eliminated from the River, water quality standards violations would continue for dissolved oxygen and elevated nutrient and chlorophyll "a " levels would persist.

Based on nonpoint source loadings and population and employment projections, the SVPDC indicated that nonpoint source pollution would increase substantially by the year 2000 and would cause water quality standard violations (SVPDC, 1986). The SVPDC developed their estimates using loading factors developed for seven pollutants and projected land use for the Basin in the year 2000. Table 4 depicts year 2000 nonpoint source loadings for each parameter for various land use activities in the Basin.

The SVPDC report concluded that the developed portion of the Basin contributes the bulk of nonpoint source pollutants, even though it only represents 50 percent of the total Basin area. Although the SVPDC did not develop loadings for pollutants other than those depicted in Table 4, they indicate that loadings for toxic pollutants, both organics and metals, would be expected to be relatively high, especially from heavy industry located near the waterfront.

The Applied Marine Research Laboratory of Old Dominion University recently completed an investigation of the relationship between land use activities and the distribution of toxicants/mutagens in the Elizabeth River system. The study found that "the potential for ecological impact appears to be site-specific, with a variety of LUA [land use activities] sites producing a variety of effects". The study also indicated considerable temporal and spatial variation in ecological effects within the system. Periodic (seasonal changes) and aperiodic (rainfall) events could cause significant differences in ambient water quality. This study documented the diffuse nature of pollutants in the system, although it was clear that specific sites (with both point and nonpoint sources) were contributing to the pollutant loads in the River. Refer to an earlier section of this report for more details of this study.

Virginia's current nonpoint source pollution control plan relies on voluntary implementation of Best Management Practices (BMPs) and enforcement of the Erosion and Sediment Control Law by local governments with technical assistance from Soil and Water Conservation Districts. The SWCB prepared a series of BMP manuals which serve as guidelines for implementing BMPs in various land use situations, including a BMP manual for urban areas. The SWCB includes BMPs as a requirement in NPDES permits as a means of nonpoint source pollution control at permitted facilities.

Many analysts agree that Virginia's nonpoint source control program has been insufficient in controlling pollution from urban areas. Many of the alternatives to reduce nonpoint pollution require substantial administrative changes and even

Table 4. Nonpoint source loading estimates for the Elizabeth River Basin based on year 2000 land use.

Parameter	Commercial/ Institutional	Light Industry	Heavy Industry	Low Density Residential	High Density Residential	Vacant/ Agricultural	Water	Total
BOD_5	565,159	464,113	73,734	528,019	179,997	95,022	–	1,906,044
TSS	4,443	3,555	565	4,094	1,264	671	–	14,592
Fecal Coliform	2,325,614	1,138,994	180,953	2,459,382	1,792,038	55,895	–	7,952,876
Total P	23,120	18,309	2,909	21,177	6,644	2,795	10,622	85,576
Total N	228,179	183,090	29,087	211,772	65,454	33,537	24,279	777,398
Lead	32,791	37,683	5,987	6,777	3,322	1,118	303	87,981
Zinc	23,120	29,805	4,735	5,082	1,636	1,118	303	65,799

Notes:

1. All factors expressed in pounds per acre per year, except as otherwise noted.
2. BOD_5 is 5-day Biochemical Oxygen Demand.
3. Total suspended solids, expressed as Factor x 10^3.
4. Fecal coliform bacteria as 10^9 cells.
5. Total Phosphorus.
6. Total Nitrogen.
7. Agricultural land has been combined with Vacant land for this analysis, because loading rates were not available from previous studies and total Agricultural acreage constituted less than 2% of Basin land area and less than 5% of the combined category.

Source: SVPDC, 1986

legislative changes governing the manner in which local governments address nonpoint source pollution. The recently created Chesapeake Bay Local Assistance Board and a state department of the same name was formed to assist communities within the Chesapeake Bay watershed to incorporate water quality protection measures into local land use plans. This is seen by many as an essential step in an effective nonpoint source pollution control program. Issues dealing with land use and development are discussed in a latter section.

SEDIMENT QUALITY

Sediment and Contaminant Dynamics

Sediments are formed when organic and inorganic particles are deposited in waters and settle out and accumulate on the bottom. These particles are deposited through erosion, point sources (industrial and municipal discharges), direct runoff, atmospheric deposition, and other nonpoint sources.

Once these particles enter a river, such as the Elizabeth, they are subject to the complex physical forces of the dynamic estuarine ecosystem. Most of the particles which enter the estuarine system are retained within it, either settling to the bottom or remaining as a mass of suspended particles near the bottom. These bottom sediments are subject to a variety of forces, both natural and man-made, which can resuspend, transport, and redeposit particles.

Toxic pollutants tend to associate with fine grained particles suspended in the water column and eventually settle to the bottom. Many toxic chemicals, such as polychlorinated biphenyls (PCBs), polynuclear aromatic hydrocarbons (PAHs), and some heavy metals are extremely insoluable in water but readily bind to sediment particles. Therefore, sediments act as a sink where compounds concentrate and are integrated over time. The contamination of Elizabeth River sediments (reports indicate that the Elizabeth contains some of the most contaminated sediments of any estuary in the world) is discussed in the following sections.

Sediment Contamination

Levels of contamination in sediments can be measured either chemically or biologically. Chemically determined compounds include conventional parameters, metals, and toxic organics. Conventional parameters include grain size, total volatile solids, total organic carbon, total volatile solids, oil and grease, biochemical oxygen demand (BOD), and sulfides. These parameters are indicators of the presence of or potential for sediment contamination. Sophisticated analytical techniques are used to measure levels of metals and toxic organic compounds in sediments.

Contamination of sediments can also be evaluated by biological assessments. The abundance, diversity, and species composition of indigenous aquatic organisms can be used as indicators of contamination. The analysis of tissues samples for the presence of contaminants, especially for organisms high in the food chain is another potential method for detecting sediment contamination.

Other methods for evaluating sediment contamination involve subjecting test organisms to sediment or sediment extracts. These tests can be performed in the field or in the laboratory. Experiments are designed to assess lethal and sublethal effects resulting from exposure to the sediments. Highly contaminated sediments usually result in acute effects (mortality), while less contaminated sediments result in chronic effects. Chronic effects can be expressed in numerous forms, varying from reduced respiration to impaired reproductive capacity to developmental deformities. Chronic effects are as significant as acute effects, because they ultimately result in a decreased viability of a population.

The bottom sediments of the Elizabeth River are highly contaminated with a variety of organic and inorganic pollutants (Alden and Butt, 1987; Huggett et. al., 1984; Johnson and Villa, 1976; Lu, 1982; Merrill and Wade, 1985; Rule,1986; Bieri, et. al. 1986). While elevated levels of pollutants occur in all segments, the highest degree of contamination occurs in the highly industrialized Southern Branch. Numerous detrimental effects have been associated with these sediments, including acute and chronic toxicity after exposure, bioaccumulation of toxicants, and an increase in incidence of anomalies in indigenous aquatic organisms.

Dredging and related activities in the Elizabeth River have received considerable attention because of the high degree of contamination of the sediments and the possible effects through resuspension and transport of contaminants resulting from these activities.

Organic Pollutants

Although several hundred organic compounds have been identified in Elizabeth River sediments, one class of compounds, polynuclear aromatic hydrocarbons (PAHs), are of particular concern. PAHs enter the environment through numerous sources, such as the incomplete combustion of fossil fuels (automobile exhausts, wood burning, industrial output), petroleum products (oil spills), and coal dust, among others. PAHs are long lived contaminants, many of which are mutagenic or carcinogenic. The levels of PAHs found in the Southern Branch of the Elizabeth River are among the highest found in any estuary in the nation.

A significant source of PAHs in the Southern Branch has been attributed to wood preserving facilities which have operated along the River since the early 1900's. Two facilities have ceased operations (one closed in 1971 and the other in 1981), but a third, Atlantic Wood Industries, continues to treat wood along the shores of the Elizabeth. Traditionally, timbers were treated with a mixture of coal tar and creosote (a coal tar distillate) to preserve the wood; creosote treated timbers are exceptionally resistant to decay and degradation, especially in the marine environment. PAHs constitute 90 percent of the chemical constituents that make up creosote (Merrill and Wade, 1985).

Several investigators have characterized the distribution of PAHs, especially the 16 EPA priority pollutant PAHs, in the Elizabeth River. Concentration of individual PAHs range from undetectable to 42 ppm. In one study, 14 generally abundant pyrogenic PAHs were identified at a concentration of 170 ppm in a single sediment sample from the Southern Branch (Bieri, et. al., 1986). Most investigators have concluded that the high level of PAH contamination in the Southern Branch is a result of marine spills, leechate, and surface runoff of creosote from these wood preserving facilities. Several studies have documented that PAH levels decrease exponentially from the areas of highest contamination (near the wood processing facilities) towards the mouth of the River.

Chemical characterization of sediments in other segments of the River indicate that additional sources of PAHs are contributing to the PAH contamination of the River sediments. Alden and Butt (1987) found that the PAH pattern observed in sediments near the Lambert's Point coal loading facilities displayed a similar pattern observed in coal mining regions in the Severn Estuary.

They concluded that fugitive coal dust from these facilities may be the source of the PAHs in that segment of the Mainstem. Another PAH pattern was observed by Alden and Butt in the lower Southern Branch which suggested a high temperature combustion source. They cited Virginia Power's Chesapeake Energy Center and two major highway crossings in the region as possible sources of the PAHs.

PAHs, although identified as a major contamination problem in Elizabeth River sediments, are not the only organic compounds of concern. Thousands of new organic compounds are synthesized each year, many of which are used in industrial processes. Many of these substances are not "target" compounds in chemical investigations, and therefore go undetected until an environmental impact has occurred. Also, many of these compounds are toxic at concentrations below the current level of detectability for the most common analytical methods.

Heavy Metals

As was the case with organic compounds, the Elizabeth reflects a high level of heavy metal contamination. Johnson and Villa (1976) evaluated the distribution of nine heavy metals from 96 stations in the Elizabeth River and characterized the main branches of the Elizabeth as follows:

Main Stem - High concentrations of chromium, iron, and aluminum and lesser concentrations of zinc occur at the entrance near Craney Island. Levels of lead, copper, cadmium, and mercury increase in a southerly direction.

Eastern Branch - The Eastern Branch has very high concentrations of copper, lead, iron, with slightly lesser, but still high concentrations of zinc, chromium, cadmium, and aluminum.

Southern Branch - The western side of the Southern Branch showed very high concentrations of lead and copper, with chromium, zinc, and cadmium also high. The eastern side showed lesser amounts of all metals except cadmium and mercury which were equally distributed on both sides.

Western Branch - Several areas had elevated levels of aluminum, iron, lead, zinc, cadmium, copper, and chromium.

Johnson and Villa compared the levels of metals they identified in the Elizabeth with levels reported for other estuaries. The sediments from the Elizabeth had two (2) to ten (10) times greater concentrations than those found in mid-Chesapeake Bay sediments or Potomac River sediments. The Delaware estuary had levels near those found in the Elizabeth. Baltimore Harbor had average concentrations twice as high for zinc and cadmium than those of the Elizabeth. The concentrations of lead, copper, and chromium were four (4), five (5), and eleven (11) times greater in Baltimore Harbor sediments than found in the Elizabeth River.

The Elizabeth River showed three (3) times the lead and zinc concentrations found in the James River, but slightly less mercury was found in the Elizabeth.

Rule (1986) found average concentrations of metals, for the Mainstem and Southern Branches, to be comparable with those reported by Johnson and Villa (1976). Rule calculated an enrichment factor to assess his geochemical data. This method allowed him to determine relative enrichment or depletion of a metal as compared to average crustal abundance. The enrichment method determines the ratio of the concentration of an element with that of a conservative element. Rule used iron as a conservative element because anthropogenic inputs of iron are relatively small compared to natural sources.

By using iron as the element for normalization, Rule was also able to compare his data to that of Johnson and Villa (1976). The enrichment factors for five metals from the Mainstem and Southern Branch of the Elizabeth and the Hampton Roads Inner Harbor are shown in Figure 4.

These studies and others indicate that the sediments of the Elizabeth River are contaminated with heavy metals. The

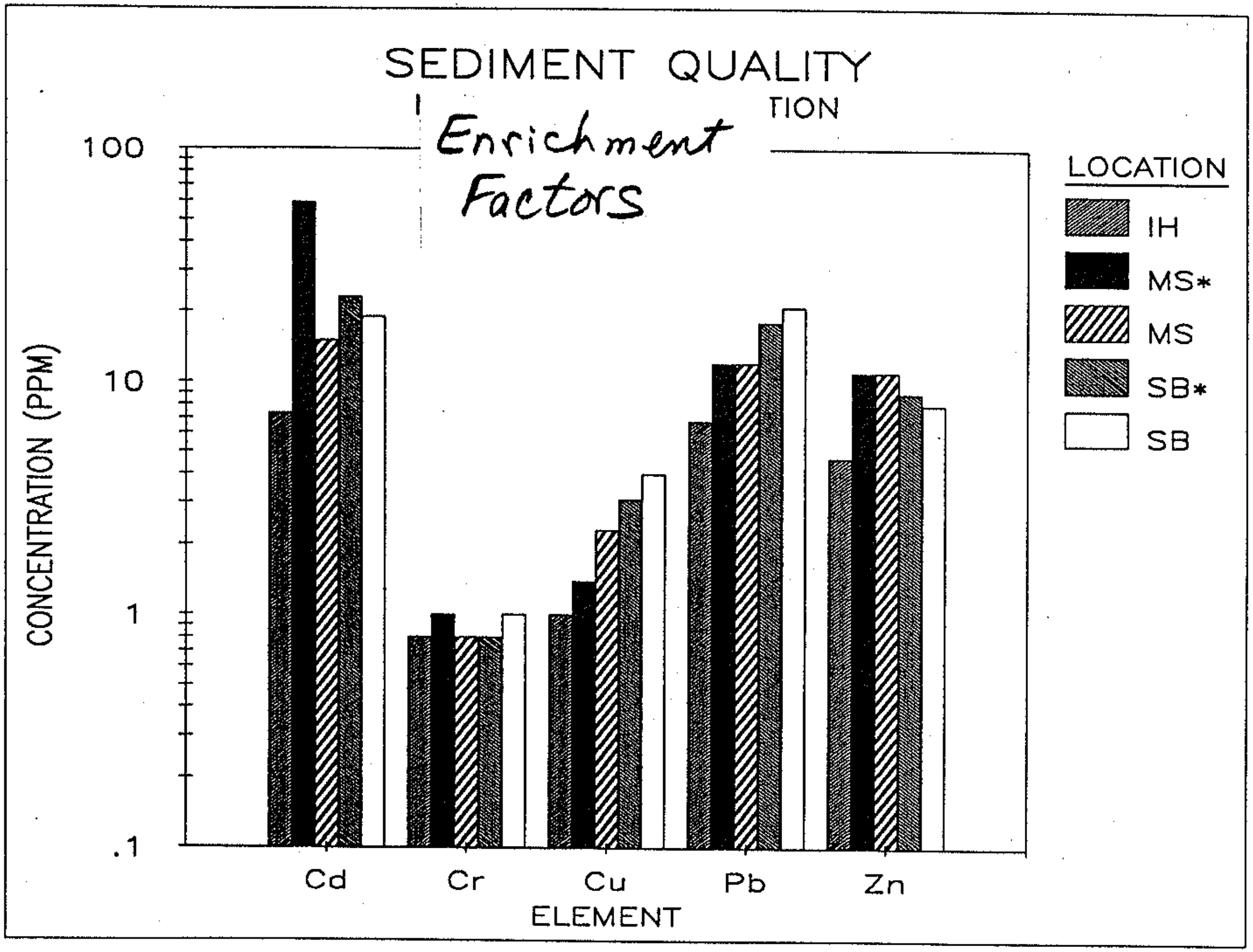


Figure 4. Elizabeth River sediment contamination (Rule, 1986). IH-Inner Harbor; MS-Mainstem; SB-Southern Branch (*-indicates data is from Jonson and Villa, 1976)

increased concentrations are a reflection of anthropogenic inputs, especially from industrial and commercial sources located among the Eastern and Southern Branches.

Sediment Toxicity

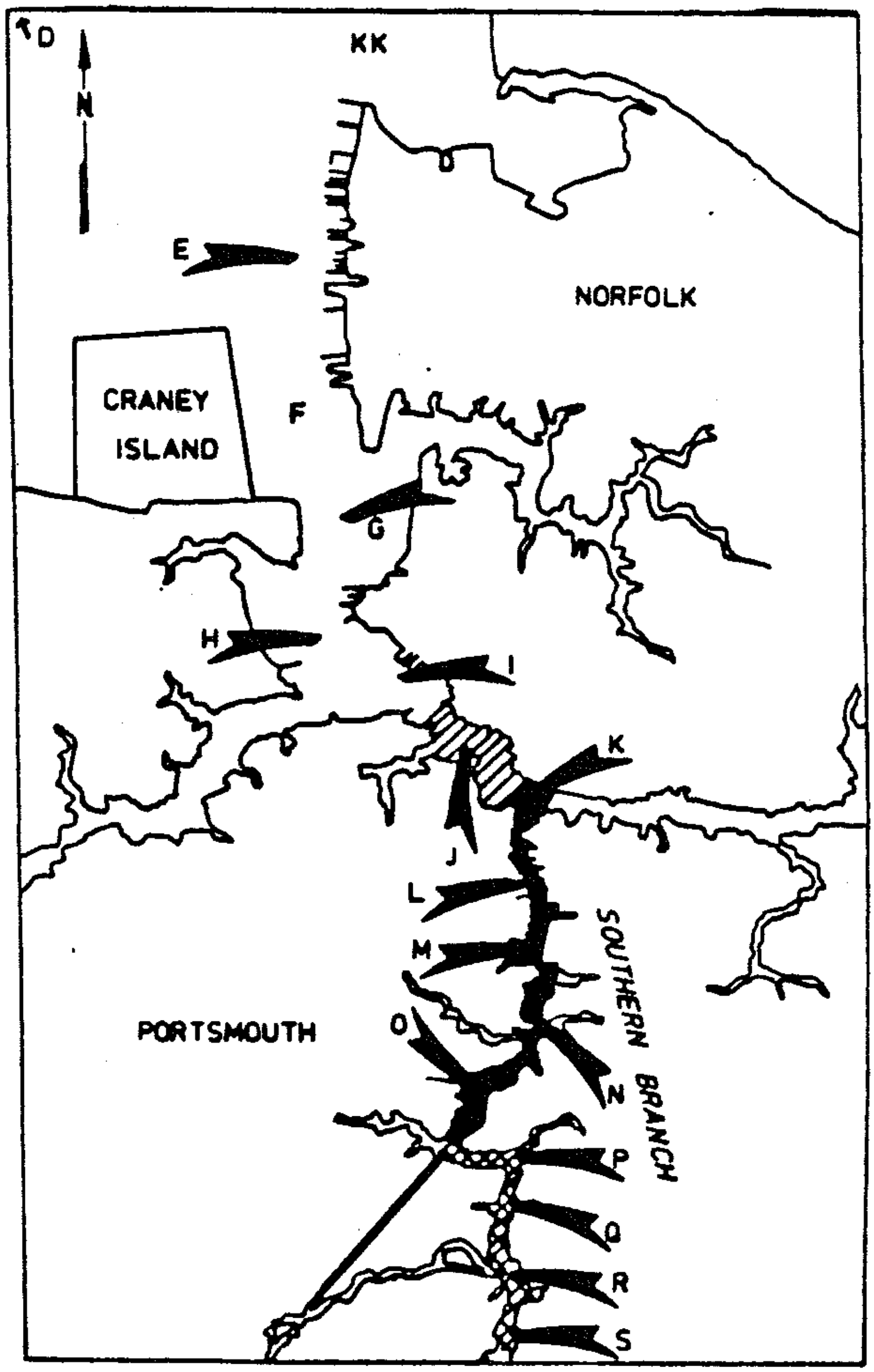
Several studies have documented the toxic effects associated with sediments from the Elizabeth River. Most studies have concentrated on the heavily industrialized Southern Branch where contaminant levels are extremely high. As mentioned previously, PAHs, many of which are mutagenic and/or carcinogenic, have been reported at extremely high levels in the sediments from the Southern Branch. The major studies documenting sediment toxicity in the Elizabeth River were conducted to assess the feasibility of open ocean disposal of dredged materials. These studies were summarized by Alden and Butt (1987) in which they classified the PAH contamination and toxicity of sediments from Hampton Roads Harbor and the Mainstem and Southern Branch of the Elizabeth River.

Most of the sediments from the Southern Branch were classified as unacceptable for ocean disposal with adjoining regions on either side being classified as transitional or of intermediate quality (Figure 5). Sediments from the Mainstem of the Elizabeth River and Hampton Roads Harbor were deemed suitable for ocean disposal because little or no biological effects were observed and/or PAH contamination was slight.

Hargis, et. al. (1984) compared the toxic effects of sediments collected from the highly contaminated Southern Branch with sediments from the relatively uncontaminated York River. Juvenile spot collected from the Ware River were subjected to sediments from each site for a period of 28 days. Additionally, spot were exposed to effluent water passing through the sediment test chambers. Fifty-six percent of the fish exposed to the Elizabeth River sediments died before the experiment concluded, while 100 percent of the fish exposed to the York River sediments survived. All of the fish exposed to the Elizabeth River sediments, including the survivors, had obvious signs of stress or disease. Many fish had external lesions, fin erosion, and other manifestations indicating significant physical stress as a result of exposure to the contaminated sediments. The control fish, which were exposed to sediments from the York River, remained healthy throughout the duration of the experiment. Although the effects were much less pronounced in the effluent experiments, the fish exposed to the Elizabeth River site effluents had significantly more signs of stress (lesions, etc.) than those exposed to the York River site effluents.

A survey of finfish from the Elizabeth River indicated a significant difference in disease incidence of fish collected from the Southern Branch as compared to those collected from the Western Branch (Owen, 1986). Over five percent of the fish collected from the Southern Branch showed some type of gross

Figure 5. Elizabeth River contaminated sediments. Unshaded areas are suitable for open ocean disposal; single cross-hatched areas represent transitional zones; and double cross-hatched areas are of questionable sediment quality (Alden and Butt, 1987)



external anomaly or anomalies. External anomalies observed included inflamed fins, fin erosion, integumental lesions, and cataracts. Disease incidence was most notable in species which were normally in contact with the contaminated bottom sediments of the Southern Branch. In laboratory experiments, Owen found that juvenile spot exposed to Southern Branch sediments inoculated with the pathogenic bacteria, Vibrio angullarium, developed significantly more cases of fin erosion than those exposed to Southern Branch sediments without the bacteria. These results support the idea that infectious diseases are more likely to occur in finfishes exposed to virulent pathogens under conditions of environmental stress.

Other investigators have indicated that finfish may avoid sections of the River where sediment contaminant levels are high. It also appears as though contaminated sediments may preclude other aquatic organisms from using sections of the River. There is evidence that some species are either tolerant or unaffected by the sediment contamination. Blue crabs support a thriving commercial fishery in the Elizabeth River, including many sections of the Southern Branch. Also, a study of the benthos of the Southern Branch reported only slight evidence of pollution affecting the benthic community.

Dredging

Dredging of sediments from the Elizabeth River and surrounding harbors is necessary to establish and maintain navigation channels, berthing areas, and docks and marinas for commercial, military, and recreational usage. Dredging and the associated disposal of dredge spoil is very controversial because of the high degree of contamination of Elizabeth River sediments and the possible effects to water quality and living resources through resuspension and transport of contaminants resulting from these activities. The SWCB identified dredging and dredge disposal as a major issue in their 1984 report "Background and Problem Assessment Report for the Elizabeth River".

The controversy surrounding dredging involves two major issues:

1. The immediate effects of dredging to water quality and living resources. Dredging has the potential to reintroduce contaminants such as heavy metals and toxic organic compounds into the water column. Contaminants, which prior to dredging may have been rendered relatively innocuous and unavailable to aquatic life, can become biologically available. In addition, contaminants can be transported by tidal currents to relatively clean areas, thus threatening additional aquatic resources.

2. Contaminated dredge material must be disposed of in an environmentally safe manner. A considerable amount of the Elizabeth River contains sediments unsuitable for fill or other constructive uses and thus must be placed in contained spoil disposal areas. Suitable sites for spoil

disposal are scarce, and there are uncertainties concerning contamination of adjacent surface and ground waters from such sites.

Dredge Activities

Hydraulic and mechanical dredging are the principal types of dredging systems used in the Elizabeth River. Hydraulic dredges remove and transport sediments in a liquid slurry, similar to a vacuum cleaner moving along the river bottom. Mechanical dredges use clamshell buckets, dippers, draglines, and other structures to remove sediments. The type of dredge used on a project is usually determined by engineering and economic constraints as well as the geophysical characteristics of a particular project.

Each method has advantages and disadvantages in handling contaminated sediments. Hydraulic dredging alters the physical and chemical conditions of the sediments as it removes and mixes the sediment with large volumes of water. Hydraulic dredging results in very little loss of sediments because of the suction used to mix the water and sediment. Sediments removed by a hydraulic system can be pumped to a nearby disposal site via pipeline or deposited in barges for transport. Hopper dredges are self-propelled ships that not only dredge the sediments, but store and transport the dredged material in internal tanks. Dredged material is either dumped directly or pumped to disposal sites. Disposing of the slurry resulting from hydraulic dredging presents an equal or greater problem than treatment and disposal of contaminated sediments.

Mechanical dredging does not significantly alter sediments nor does it introduce much additional water, but considerably more sediment is lost from this type dredge than from hydraulic dredges. Mechanical dredges typically place dredge material in barges so that it can be transported to disposal areas. The ACOE has evaluated modifications of hydraulic and mechanical dredges and their use to reduce the detrimental effects of dredging. These modifications may be as simple as modifying a clamshell dredge to make it watertight or be extremely complex and involve new technologies in hydraulic dredging. Another mechanism to reduce the effects of dredging is to restrict dredging operations to periods which will result in the least impact. This may involve reducing dredging operations during the summer when dissolved oxygen levels are low or scheduling dredge operations to reduce the impact on aquatic resources, such as spawning fish.

Extensive investigations of the immediate effects of dredging have reached the general conclusion that dredge activities have little or no effects on water quality or living resources (Tramontano and Bolen, 1984; Goodwin and Michaelis, 1984; Tayolaro and Mansky, 1985). Most studies revealed that dredging produced only a near field phenomenon with only minor variations in water quality. Ambient conditions were established in most cases within several hundred meters of the dredge and plumes did not last for more than 24 hours after dredging. Tramontano and Bolen (1984) estimated that storm events produced estuary wide variations (as opposed to near field) nearly an order of magnitude greater than that of a dredge operation they evaluated on the Thames River in Connecticut. There is a general consensus that spoil disposal is of more concern environmentally than dredge operations.

There is an obvious lack of information regarding the environmental effects of dredging operations in the Elizabeth. Although, as previously noted, most dredge operations result in relatively minor impacts, this may not be the case for the Elizabeth. With an extremely high level of contamination and poor flushing capabilities, dredging operations in the Elizabeth, especially the Southern Branch, may be of concern. Baseline information to assess the affects of dredging operations in the Elizabeth are required before recommendations can be made concerning the affects of dredging operations in the Elizabeth.

Historically, the channels in the Elizabeth River were dredged by U.S. Government hopper dredges, but more recently pipeline dredges and clam shell dredges have been used in the Elizabeth River. The ACOE is currently involved in various phases of the Norfolk Harbor Project, which will result in the deepening of the main channel of the Elizabeth River. The channel will be deepened to 55 feet, from its current depth of 45, from Lamberts Point to the Hampton Roads Harbor. The channel, from Lamberts Point to the Norfolk and Western Railroad Bridge in the Southern Branch will be deepened from 40 feet deep to 45 feet deep and from the Norfolk and Western Railroad Bridge to U.S. Routes 13 and 460 bridge the channel will be deepened to 40 feet. The channel will be maintained at 35 feet from this point to the upstream limit of the project. The Eastern Branch channel will be maintained at a depth of 25 feet to upstream limit of the project (2.5 miles upstream from the confluence with the Southern Branch). A channel 24 feet deep in the Western Branch will be maintained for a distance of 1.7 miles from the main channel.

The frequency of maintenance dredging and quantities dredged from the River vary as a result of channel sedimentation processes and funding appropriation levels. The average frequency and quantities for the major Hampton Roads maintenance dredging operations are depicted in Table 5.

The dredging of well maintained navigation channels usually results in relatively clean materials, although this is not always the case for the Elizabeth. Alden and Hall (1984) sampled sediments from the channel near defunct wood preserving sites in the Southern Branch prior to and at periods of 12 and 18 months after the ACOE had extensively dredged this section of the River. The sediment samples were analyzed for priority

Table 5. Hampton Roads Dredging Data Summary.

Authorized Project Feature	Normal Maintenance Dredging Interval (years)	Normal Quantity Per Maintenance (cubic yards)	Average Annual Quantity Removed (cubic yards)
Norfolk Harbor 45& 50 ' Channel	1-2	1,000,000	1,000,000
Norfolk Harbor 40 ' Channel	10	500,000	50,000
Southern Branch 35 ' Channel	5	400,000	80,000
Anchorage Opposite Sewells Point	3	900,000	300,000
Channel to Newport News	5	600,000	120,000
Anchorage Opposite Newport News	5	500,000	100,000
Craney Island Rehandling Basin	2	2,000,000	1,000,000

Source: Army Corps of Engineers, Norfolk District, Dredging Management Branch pollutant PAHs. The pre-dredge sediments contained extremely high levels of PAHs. Sediment samples collected nearly one year after dredging had only moderate levels of PAHs, but within 18 months an increase in PAH contamination had occurred. Input from new sources or more likely the input of PAHs through slumping and transport of sediments from the sides of the channels was considered responsible for the observed increase. The lack of information regarding the contaminant dynamics of the Elizabeth makes it difficult to predict whether the sediments would ever obtain the levels of contamination prior to dredging. Thus, the effectiveness of dredging channels in the Southern Branch to reduce contaminant levels is questionable.

Dredge Disposal

There are several options available for the disposal of dredge material. Unconfined open water disposal requires dredge material to be transported to and dumped at designated sites. Only relatively clean sediments can be disposed in this manner because the sediments are directly exposed to aquatic life and can be transported and redistributed in the area. The ACOE has evaluated the potential for dumping sediments from Hampton Roads Harbor at the proposed Norfolk dump site which is located about 16 miles east of the entrance to the Chesapeake Bay. Sediment dumped at this site would have to meet specific criteria for the protection of aquatic life. The sediments from much of the Elizabeth River, especially the Southern Branch, would not meet the criteria for open water disposal.

Contaminated sediments must be disposed of in confined disposal areas. They can be categorized as aquatic capped, nearshore confined, and upland. In aquatic capped disposal operations, the dredge material is placed on the ocean bottom or in a depression or bermed area on the ocean bottom and a cap of clean sediment is placed over the entire area. Nearshore confined disposal requires the construction of containment berms in the water near the shoreline and dredged material is pumped into the containment areas resulting in an increase of land area. The ACOE's Craney Island Dredge Disposal Facility is an example of a nearshore confined disposal site. Upland disposal involves placing dredged material in depressions or diked areas away from the shore.

The Craney Island Dredge Disposal Area is located at the entrance to the Elizabeth River, west of the Norfolk Harbor Channel. The four square mile site (1,012 hectares) is bounded by sand dikes on each of the three sides and by the mainland to the south. The disposal area was constructed in the early 1950's by the ACOE to receive dredge materials removed during dredging and construction activities in the Hampton Roads area. The site was designed to hold about 96 million cubic yards and had a projected life of 22 years. The first dredge materials were placed in the disposal area in 1955 and by 1972, 100 million cubic yards of sediments had been placed in the site. The additional storage capacity is a result of the rising of the dikes from 8 feet above mean low water to approximately 15 to 28 feet above mean low water. In the absence of suitable alternatives, the ACOE will continue to use the disposal site to its maximum potential.

Usually, dredge material is not directly pumped into Craney Island, but is dumped into the 35 acre, 40 feet deep, rehandling basin located on the east side of the island. Dredge spoils are dumped into the basin and then pumped to the island when the basin is full. The process saves time and money.

In response to concerns that pollutants dumped into the rehandling basin might drift out of the basin and affect water quality in Hampton Roads, the Virginia Institute of Marine Science (VIMS) conducted a physical and chemical study of the rehandling basin. The VIMS study, although only performed on a single disposal operation of sediments from the Eastern Branch of the Elizabeth, indicated that only minor variations in water quality occurred after dredge material was dumped into the rehandling basin. Ambient conditions returned within hours after the dumping was finished. VIMS cautioned that different sediments may not produce similar results.

Old Dominion University's Applied Marine Research Laboratory performed a series of extensive chemical and biological investigations to evaluate the sediment quality within the Craney Island Disposal Facility. They found that levels of heavy metals and PAHs were relatively low throughout the disposal site. The western ponding area had the poorest sediment quality and toxicity testing suggested a similar pattern, though biological effects were minimal. Most of the sediments tested would meet the criteria developed by the ACOE for open ocean disposal, indicating that dilution and weathering had reduced contaminant levels.

It has been suggested that uncontaminated material from Craney Island could be disposed of in the open ocean, thus extending the life of the disposal facility. This would extend the facility's ability to continue receiving the contaminated sediments from the Elizabeth River. The ACOE is evaluating this and other disposal alternatives to provide for future needs in the Hampton Roads area.

LIVING RESOURCES

The environs of the Elizabeth River, although stressed, are still inhabited by a variety of aquatic and terrestrial organisms. Most studies focus on the aquatic life of the Elizabeth River because they are sensitive indicators of the environmental quality of the estuary. The aquatic life inhabiting the Elizabeth River can be categorized into three broad groups: Benthic organisms, plankton, and finfish. Although the aquatic life inhabiting the Elizabeth River has not been studied as extensively as other estuaries in the area, such as the James and York Rivers, several studies have provided valuable insights into the biological character of the Elizabeth River. The terrestrial environs surrounding the Elizabeth River have received even less attention, with the majority of the information resulting from projects requiring environmental impact assessments. Unfortunately, most of this information has been gleaned from the literature and is not the result of formal investigations. The following is a brief summary of the living resources which inhabit the Elizabeth River with particular emphasis on how the communities reflect the environmental quality of the Elizabeth River.

Macrobenthic Communities

Macrobenthic communities are composed of invertebrate organisms which live in or on the bottom. Such communities often include molluscs (i.e. oysters, clams), crustaceans (crabs), and marine annelids (worms) as well as a myriad of other invertebrate organisms. Benthic organisms are important components of the estuarine environment; they perform an important recycling function and are an important food resource for many fishes.

In addition, benthic communities are often considered the best biological indicators of water and sediment quality. Benthic communities serve as biological indicators in several fashions. Several species of benthic organisms are considered pollution indicators. Such species are pollution tolerant and thrive in polluted habitats which exclude or reduce the density of non tolerant species. However, the use of indicator species is somewhat controversial, therefore more complex analyses of benthic community structure are often required to determine pollution effects. The structure (species composition and densities) of benthic communities subjected to pollution is compared to the structure of benthic communities which occupy similar non polluted habitats. Differences in benthic community structure may be attributed to pollution effects.

One might expect that the Southern Branch, with reportedly high levels of contamination, might be devoid or at least depauperate of benthic organisms. Hawthorne and Dauer (1983) investigated the benthos of the Southern Branch and found that there was only a slight indication that the communities were stressed. Most benthic studies in the Elizabeth River have been focused in the Mainstem (Boesch, 1971; Richardson, 1971; Nus, 1975; HRSD, 1979). Polycheates, molluscs, and crustaceans were the dominant organisms collected during these studies. These studies concluded that macrobenthic communities in the Elizabeth River were mildly to moderately stressed as a result of pollution. Several of the dominant species in Elizabeth River benthic communities, such as the polycheate <u>Streblospio</u> <u>benedicti</u>, are considered pollution tolerant species. Elizabeth River benthic communities also differed in community structure when compared to benthic communities occupying similar habitats in the James and York Rivers. These differences were usually attributed to pollution in the Elizabeth River.

Plankton

Phytoplankton, which are microscopic plants, are primary producers serving as the basis of the food web in the estuarine ecosystem. Zooplankton are microscopic animals which feed on phytoplankton and serve as a food source for larger animals. Ichthyoplankton is the planktonic lifestage of fish (i.e. eggs and larvae). Time of year, tidal exchange, current patterns, salinity, temperature, and other environmental factors, including pollution, influence plankton species composition and abundance.

Being the major autotrophic producer in marine and estuarine ecosystems, phytoplankton has been widely studied in the Chesapeake Bay and its tributaries. Chlorophyll "a", an indirect measure of phytoplankton biomass, is often used to determine if eutrophic conditions exist in estuaries (i.e. nutrient enriched).

The major phytoplankton components of the Elizabeth River are diatoms and dinoflagellates. Diatoms are dominant during the winter months, and dinoflagellates are usually dominant during the warmer months. This pattern is very similar to phytoplankton patterns observed in the lower Chesapeake Bay. The diatom, _Skeletonema costatum_, was an important species in all phytoplankton studies conducted in the Elizabeth River. Phytoplankton blooms have been reported for the Eastern and Southern Branches of the Elizabeth River during the summer months. Chlorophyll "a" levels are usually higher in the Elizabeth River than in the James, Hampton Roads, or the Chesapeake Bay.

A recent study indicated that chlorophyll "a" levels were greater in the Eastern and Western Branches than in the Mainstem and Southern Branch. The Southern Branch sampling station in this study was located near Atlantic Wood Industries. Pollution sources may be responsible for the low chlorophyll "a" values because the dominant phytoplankter in this study, _Skeletonema costatum_, (reported to be susceptible to chlorinated hydrocarbons) was 2.5 to 3 times less abundant than at other stations.

The zooplankton communities in the Elizabeth River are similar to other Chesapeake Bay area communities and are affected by similar environmental factors which affect phytoplankton.

The presence of ichthyoplankton, fish eggs and larvae, indicate that an estuary is used as a spawning area or as a nursery area for larval and juvenile fish. Studies of ichthyoplankton composition and abundance indicates that several species use the Elizabeth River as a spawning or nursery area.

Adult spot spawn along the coastline and in the mouth of the Chesapeake Bay from November to January, and post-larvae and juveniles move into the Chesapeake Bay in April. Juvenile spot concentrate in shallow estuarine waters, including the Elizabeth River, and remain in the estuary until late fall. Juvenile croaker are taken in the Elizabeth River, indicating that they also use the Elizabeth River as a nursery ground. Croaker remain in the Elizabeth River during the winter, concentrating in the deeper sections. Other species which use the Elizabeth River, either as a spawning area or nursery ground, are gobies, Bay anchovy, tidewater silversides, menhaden, and American eel. Gizzard shad and yellow and white perch have been reported in the upper reaches of the Southern Branch.

Finfish

The use of the Elizabeth River by finfish varies seasonally. Some species, including the Bay anchovy, silverside, oyster toadfish, hogchoker, and several others are permanent residents of the Elizabeth River. White and yellow perch inhabit the upper reaches of the Southern Branch. Adult spot, weakfish, croaker, and summer flounder use the lower reaches of the Elizabeth River as a feeding area during the summer months. Blueback herring, Alewife, and striped bass have been reported from the Elizabeth River during the winter months.

Birdsong (1984) evaluated finfish populations from the Elizabeth River and lower Chesapeake Bay and speculated that pollution influences finfish abundance and diversity in the Southern Branch of the Elizabeth River. Birdsong suspected that the infrequent collection of yearling or older spot from the Southern Branch, as compared to the Mainstem, was the result of avoidance of the polluted Southern Branch by these fish. Birdsong, among others, has documented high incidences of diseased fishes in the Southern Branch (Hargis, et. al.,1984; Owen,1987). Gross anomalies, such as fin erosion or inflammation, cataracts, and external lesions are observed at much higher rates from fish collected in the Southern Branch than from other segments of the Elizabeth River. The highest rates of anomalies occur on species that are resident fish or spend a high percentage of time in contact with the river bottom.

Tidal Wetlands

Urbanization and development of the shoreline of the Elizabeth River has drastically reduced the acreage of tidal wetlands in the Elizabeth River system. Tidal wetlands have been recognized as a valuable estuarine community which provides habitats for fish and wildlife, reduces shoreline erosion, protects water quality, and is an integral part of the estuarine ecosystem. As part of the Virginia Wetlands Act, VIMS has the responsibility of developing an inventory of Virginia's tidal wetlands. VIMS has published the marsh inventory for the City of Virginia Beach and the City of Norfolk (Silberhorn et. al., 1979; Silberhorn and Priest, 1987). Tidal wetland inventories for the Cities of

Chesapeake and Portsmouth have not been published. Saltmarsh Cordgrass marshes, an extremely productive and valuable marsh community, and Saltbush marshes are the predominant marsh communities cited in the inventories. VIMS stresses the importance of preserving and restoring these wetlands to enhance the ecosystem.

URBAN GROWTH AND DEVELOPMENT

As part of the CERWQMP, the SVPDC examined land use in the Elizabeth River Basin (SVPDC,1986). The SVPDC examined the comprehensive plans of the Basin communities to develop a land use schematic for the Basin. The SVPDC's evaluation was also based on the 1978 land use forecast prepared as part of the HRWQMP and population and employment forecasts prepared as part of the 1978 HRWQMP and 1983 HRWQMP Update. The SVPDC's analysis indicated that the majority of the Riverfront will continue to be used for military, industrial and transportation related activities, with all major land use categories being represented.

The SVPDC summarized the projected Year 2000 land use forecast as follows; "Even with the significant growth in population and employment projected for the remainder of the century, nearly 40 percent of the Basin's land area will remain in agricultural use or in an undeveloped status. Approximately 20 percent of the area will be developed for low density (1-7 units per acre) residential use. High density (greater than 7 units per acre) will occupy approximately 3 percent of the area. Light industrial activities, including warehousing, will occupy 21,289 acres or 15 percent of the Basin. Heavy industrial activity will occur on only slightly more than 2 percent of the land. Approximately 10 percent of the Basin's land area will be devoted to commercial and institutional activities."

The upper reaches of most River segments will experience intensified residential development. Commercial and industrial uses will be concentrated in the Eastern and Southern Branches, with nearly 90 percent of the heavy industry located in these branches. These segments will also contain about 75 percent of the commercial and institutional acreage in the Basin. Most of these uses will be located on or in close proximity to the shoreline.

In their report, the SVPDC identified parcels/uses of concern in the Basin. These areas are defined as transitional parcels that are either vacant or have low impact uses, but will most likely experience intensification of use. The SVPDC identified 28 parcels within the Basin as transitional parcels of concern (Table 6). Also, parcels which involve the "generation, transportation and/or treatment, storage or disposal of hazardous wastes" were identified as uses of concern. The SVPDC estimated that as many as 1,350 firms in Southeastern Virginia

Table 7. Transitional Parcels of Concern.

Name	Current Use	Future Use
Naval Base	Industrial	Industrial-Use Intensification & Paved Areas
Norfolk Int. Terminals	Industrial	Industrial-Use Intensification
Craney Is. Disposal Area	Dredged Material Disposal	Same, Industry
Lamberts Pt. Landfill Landfill	Vacant-Closed	Recreation
Cox Site	Vacant	Industrial
Beasley Property	Vacant	Mixed Use
Pinners Pt.	STP	Unknown
Scotts Cr.	Vacant-Mixed	Industrial Harbor Serv.
St. Helena	Industrial	Industrial-Use Intensification
Campostella Landfill	Closed Landfill	Unknown
Allied	Industrial	Industrial
St. Juliens	Industrial	Industrial-Use Intensification
Columbia Yacht	Industrial	Industrial-Use Intensification
E.R. Shores	Vacant	Residential-Unknown
GSH Site	Vacant	Mixed Use
Raby Road	Vacant	Unknown

Table 7. Continued

Name	Current Use	Future Use
Downtown 17 Acres	Vacant Parking	Mixed Use
Bessie's Place	Commercial Vacant	Unknown
Lafayette Shores	Multi-Family	Mixed Density Residential
Port Centre	Vacant	Commercial
Gulf Oil	Oil Terminal Closed	Industrial-Use Intensification
J.G. Wilson	Industrial	Industrial-Use Intensification
Farmer's Export	Vacant	Industrial
Smith-Douglas	Industrial	Industrial-Use Intensification
Gilmerton	Vacant	Mixed Use-Marina
Dominion Boulevard	Industrial & Vacant	Industrial-Use Intensification
Bowers Hill	Vacant	Unknown
W. Branch	Vacant	Mixed Use & Commercial

Source: Southeastern Virginia Planning District Commission, 1986.

may come under hazardous waste regulatory controls (SVPDC, 1986b). The SVPDC also estimated that there may be as many as 12,320 underground storage tanks in Southeastern Virginia, of which 10-35 percent may be leaking. It can be assumed that a significant portion of the tanks may be found in the heavily urbanized Elizabeth River Basin.

The SVPDC concluded that the Basin will experience intensified development along the River's shore, especially the Eastern and Southern Branches where it is expected that employment related development will continue. Please refer to the referenced reports for further details concerning land use in the Basin, in particular the 1978 HRWQMP land use forecast and SVPDC's 1986 report, "CERWQMP: Institutional Analysis and Land Use/Nonpoint Source Analysis".

POINT SOURCE POLLUTION CONTROL

Industrial, municipal, and federal facilities discharge millions of gallons of effluent per day into the Elizabeth River. Unpermitted discharges, stormwater runoff, sewage overflows and spills contribute even further to the discharge of pollutants to the River. This section will focus on the control of pollutants from VPDES permitted dischargers and the search for unpermitted discharges. Stormwater runoff, raw sewage overflows, and transient sources of pollutants will be discussed in the nonpoint section.

The NPDES program was created with the intent of controlling all types of pollutants, but initially the program concentrated on the control of conventional pollutants. The program has achieved considerable success in controlling such pollutants, but recently a shift in emphasis to the control of toxicants has revealed that the program is insufficient to prevent the discharge of toxic pollutants.

Toxic pollutants which may originate from numerous sources, such as industrial byproducts or process waste, have the potential to seriously impact the environment. The discharge of toxicants can result in serious impacts which are immediately observable, such as fish kills, but more often toxicants accumulate in the tissues of indigenous aquatic life and in the bottom sediments of the system. The effects of the discharge are only realized after serious and sometimes irreversible environmental damage has occurred.

Although industrial facilities are usually considered the major contributor of toxicants, municipal facilities which receive industrial waste have also been targeted as potential sources for the discharge of toxicants. The NPDES pretreatment program provides a degree of control for the input of toxics into municipal treatment systems, but often the treatment is not capable of removing all toxic compounds. Treatment plants are not designed to remove toxic compounds, therefore any removal of toxicants is incidental.

Virginia's NPDES program (VPDES), as with most other NPDES programs, is based on several key components. The VPDES program requires that; 1) Dischargers must apply for an VPDES permit and supply the State with certain information regarding the location, flow, and nature of the discharge, 2) Permit writers use this information to apply permit limits which will insure that the State's policies, regulations, and standards for water quality are maintained, 3) Monitoring requirements are included in the permit to insure compliance with permit limits, and 4) the facilities are periodically inspected for compliance with permit requirements.

Most regulatory agencies which administer the NPDES program would agree that there are inherent weaknesses in the program. Several issues within the current NPDES program must be addressed, especially if the SWCB is to effectively control toxics. Limitations of the current program are summarized below;

- Toxic limits are not routinely included in permits. There is insufficient data for most toxicants to develop numerical limits for inclusion into permits.

- Toxic compounds are diverse in nature. Procedures used to describe mixing zones for conventional parameters do not apply to toxic compounds.

- Past enforcement actions have been insufficient or non existent.

- Compliance inspections are infrequent and preannounced.

- There is no system to detect unpermitted discharges.

- There is no system by which to audit the self-monitoring program.

- The laboratory inspection program does not apply to toxics and biological monitoring.

- Operator training is insufficient.

- The SWCB requires additional resources to implement, manage, and enforce the toxics management program.

Goal
Reduce or eliminate the discharge of pollutants into the Elizabeth River by industrial, municipal, and federal facilities.

Strategy
Issue VPDES permits to all significant dischargers to the Elizabeth River with appropriate requirements for the control of toxic substances. The requirements may also require an assessment of the water and sediment quality in the vicinity of the outfall.

Implement compliance and enforcement programs, some of which are in place and others yet to be developed, will insure quick and efficient responses to permit violations and insure future compliance.

Additionally, increased resources will be allocated to the assessment of discharges and their impact, inspection and enforcement of VPDES permits, and the discovery of unpermitted discharges.

Recommendations

Permits

P1.1 Toxics Management Program (modifications or additions to the current program)
-Data comparability with ambient monitoring programs.
-Tiered approach to toxics monitoring.
-Develop alternate acute and chronic toxicity tests.
-Require water quality monitoring at dilution zone boundary.
-Require biological monitoring in vicinity of outfall(s).
-Require sediment monitoring in vicinity of Outfall(s).
-Develop TMP data management program.

P1.2 Permit fees for all majors and minors with TMPs.

P1.3 Revise procedures manual for permit writers with increased emphasis on toxics management and monitoring.

P1.4 Priority list of permits to reopen (with schedule).

P1.5 Reopener provision to allow quick and efficient modification of permits as needed.

P1.6 Strengthen BMP language in permits.

P1.7 Strengthen SPCC and WCPC plans.

P1.8 Develop handbook for VPDES permittees.

P1.9 Increase resources to fulfill program requirements.

Standards and Criteria

P2.1 Adopt EPA Water Quality Criteria for Priority Pollutants.

P2.2 Identify toxic compounds for which numerical limits should be developed and initiate the standards development process for these compounds.

P2.3 Develop criteria for sediment classification (See Contaminated Sediments and Dredging Action Plan).

P2.4 Incorporate Standards and Criteria for water and sediment quality into SWCB Toxics Management Program.

Compliance Assurance

P3.1 Increase frequency of inspections;

	# of Inspections/year Complete lab/facility	Spot check
Majors	4	as needed
Selected Minors	2	as needed
All Others	1	as needed

P3.2 Unannounced inspections.
P3.3 Additional inspections based on compliance record.
P3.4 Independent verification of self-monitoring program.
P3.5 Continue to enhance the NOV program.
P3.6 TMP data incorporated into NOV program.
P3.7 Develop SWCB enforcement guidelines into a regulation.
P3.8 Administrative penalties.
P3.9 Felony provisions for willful violations.
P3.10 Public notice of permit violations and enforcement actions.
P3.11 Develop lab certification program for conventional, toxic, and biological parameters.
P3.12 Increase resources to fulfill program requirements.

<u>Additional elements</u>

P4.1 Search for unpermitted discharges.
P4.2 Identify sites/facilities requiring VPA permits.
P4.3 Municipal and industrial operator training and certification.
P4.4 Enhance public education programs.

NONPOINT SOURCE POLLUTION CONTROL

It has been estimated that nearly half of the pollutants which enter our nation's streams and rivers come from nonpoint sources (EPA,1987). The CWA of 1972 provided for the development of plans and strategies to control both point and nonpoint sources of pollution, and the Water Quality Act of 1987 provided the impetus for States to implement nonpoint source control plans. The Chesapeake Bay program has also emphasized the importance of nonpoint source pollution control if we can expect to achieve the goals of restoring and preserving the Chesapeake Bay. Nonpoint source control presents an enormous task because of the diverse and diffuse nature of nonpoint source pollution.

Nonpoint source pollutants usually enter water bodies as a result of storm events. Pollutants which accumulate during dry weather are carried into rivers and streams with stormwater during rainfall events. Nonpoint source pollutants vary by source and have varying effects on the waterbodies which they enter. The discharges of sediments, nutrients, and pesticides from agricultural lands have received considerable attention, primarily because they represent such a large percentage of nonpoint source pollution. Urban and suburban areas, such as those of the Elizabeth River Basin, present special nonpoint source pollution control problems. Studies of urban pollution have demonstrated that commercial, industrial, residential, and even vacant lands contribute a variety of pollutants, including many toxic pathogens, heavy metals and organic compounds, to surrounding water bodies.

Nonpoint source pollution presents a major obstacle in achieving water quality in the Elizabeth River (HRWQA, 1978). The SVPDC concluded that nonpoint source pollution in the Elizabeth River Basin would increase substantially by the year 2005 and would result in water quality standards violations (SVPDC,1987).

Virginia's current nonpoint source pollution control plan relies on voluntary implementation of Best Management Practices (BMPs) and enforcement of the Erosion and Sediment Control Law by local governments with technical assistance from Soil and Water Conservation Districts. The SWCB prepared a series of BMP manuals which serve as guidelines for implementing BMPs in various land use situations, including a BMP manual for urban areas. Most analysts agree that Virginia's nonpoint source control program has been insufficient in controlling pollution from urban areas. Many of the alternatives to reduce nonpoint pollution require substantial administrative changes and even legislative changes governing the manner in which local governments address nonpoint source pollution. Issues dealing with land use and development will be discussed in a latter section.

Goal
Protect the Elizabeth River and its resources from contamination by nonpoint source pollutants.

Strategy
Nonpoint source loadings of contaminants will be reduced by developing 1) public education programs and public support for nonpoint source pollution control, 2) economic incentives to control nonpoint source pollution, 3) regulatory measures, and 4) research on nonpoint source control in the Elizabeth River Basin.

Recommendations

Stormwater management

N1.1 Develop stormwater management strategy for the Elizabeth River Basin which will include;
- -Inventory of existing stormwater drains
- -Monitoring of target drain systems
- -Spill response program and remedial action guidelines
- -Program for the installation, operation, and maintenance of nonpoint source control devices
- -Programs to develop local funding for nonpoint source control

N1.2 Update of SWCB's Urban BMP manual to include the most recent information and technologies to control nonpoint source pollution.

N1.3 Provide economic incentives for nonpoint source pollution control demonstration projects.

N1.4 Require NPDES permits for all stormwater discharges from industrial, commercial, and federal facilities.

N1.5 Strengthen BMP requirements in NPDES permits.

N1.6 Increase compliance/inspection programs for BMPs at NPDES permitted facilities.

N1.7 Fund research for stormwater retention/detention/ treatment programs in the Elizabeth River Basin.

N1.8 Require Department of Defense to upgrade stormwater control at federal facilities.

N1.9 Mandatory BMPs for facilities handling toxic/hazardous wastes or having outside storage of materials.

Water-based nonpoint source control

N2.1 Enhance regulations to control the discharge of pollutants from boats.

N2.2 Increase compliance/enforcement of vessel discharge regulations.

N2.3 Felony provisions for illegal discharges from boats, marinas and docks.

N2.4 Increase the number of pump-out facilities in the Lower Chesapeake Bay and Tributaries.

N2.5 Ban the use of TBT in Virginia.

Education/Information programs for nonpoint source control

N3.1 Enhance public education programs for residential nonpoint source control.
N3.2 Implement public education programs at Marinas and Docks.
N3.3 Provide training seminars for public utility personnel and environmental managers.
N3.4 Provide training seminars for industrial plant operators and managers.

Additional elements

N4.1 Utilize USGS's Elizabeth River GIS to identify potential nonpoint sources of hazardous/toxic waste.
N4.2 Investigate potential nonpoint sources of hazardous/toxic waste.
N4.3 Require VDOT to install NPS controls into new highway projects and retrofit significant existing highways.
N4.4 Require VDOT to insure BMP implementation during construction activities.
N4.5 Require HRSD and city utilities to upgrade pump stations, force mains, and sewage control equipment.
N4.6 Develop RSO reduction plans.
N4.7 Investigate the use of wetlands as nonpoint source controls in the Elizabeth River Basin.

CONTAMINATED SEDIMENTS AND DREDGING

The sediments in many segments of the Elizabeth River are highly contaminated with heavy metals, organic compounds, and other potentially toxic or harmful substances. Contaminated sediments in the Elizabeth River are a result of years of input from point and nonpoint sources. Documented spills and surface runoff from industrial sites, especially wood preserving facilities, have been implicated as the cause of severe PAH contamination in the Southern Branch.

Various biological assessments conducted on the sediments of the Elizabeth River indicate that toxic hot spots occur throughout the River. Sediments from Southern Branch and portions of the Eastern Branch and Mainstem show the highest levels of toxicity. This information generally correlates with observed contaminant levels.

Dredging is necessary to create and maintain docks, berths, and navigation channels in the Hampton Roads area. The ACOE has begun parts of the Norfolk Harbor Deepening project which proposes to deepen the main channels of the Elizabeth River and Hampton Roads Harbor. Dredge activities are regulated through a combined state and federal permit system. The SWCB reviews ACOE 401 permits and is involved in some sediment characterization studies, but lacks established goals, guidelines, or criteria for sediment quality in the Elizabeth River. The ACOE has developed specific criteria for determining whether sediments are suitable for open ocean disposal. Sediments from the Southern Branch and a portion of the Mainstem will not meet these criteria.

Contaminated sediments (those not meeting the ACOE criteria) must be deposited in the Corp's Craney Island Disposal facility. This site has exceeded its original capacity and is being modified by the ACOE so that it may continue to be used as needed by the ACOE. The ACOE is currently evaluating alternative disposal sites and plans to reduce the use of the Craney Island site. The Craney Island facility will be reserved for the most contaminated sediments.

Goal
Reduce the adverse effects on water quality and biological resources, resulting from contaminated sediments and dredging activities in the Elizabeth River Basin.

Strategy
To achieve this goal, the State Water Control Board will develop sediment quality goals and guidelines, identify toxic hot spots and develop priorities for remedial actions, and continue to coordinate dredge and disposal related activities with the ACOE.

Recommendations

Policy

S1.1 All federal, state, and local programs should be directed towards eliminating point and nonpoint sources of contaminants.
S1.2 Federal and state programs involving dredging and disposal shall be designed to minimize adverse effects.
S1.3 Remedial actions will be taken, when possible, to remove contaminated sediments from the system which result in adverse effects.
S1.4 The State Water Control Board and other state and federal agencies will seek enforcement and legal actions to recover costs associated with cleanup activities.

Contaminated Site Investigation

S2.1 Compile inventory of sediment contamination in the Elizabeth River.
S2.2 Develop goals and guidelines for sediment quality.
S2.3 Investigation of point and nonpoint sources of contamination (USGS GIS).
S2.4 Develop ranking procedure for identified hot spots.
S2.5 Develop remedial action plans for high priority sites

Dredging and Disposal

S3.1 Continue joint 401 permit review and issuance with ACOE. Use State sediment quality goals and guidelines to make decisions.
S3.2 Review major EISs to insure compatibility with established sediment quality goals and guidelines.
S3.3 State Water Control Board shall coordinate with ACOE and VMRC to schedule dredge and construction activities so that adverse impacts are reduced.
S3.4 State Water Control Board shall assist ACOE in evaluating disposal site alternates to ensure compatibility with State Water Quality goals and standards.

COMPREHENSIVE MONITORING PROGRAM

Monitoring of environmental parameters is an essential element in understanding the physical, chemical, and biological processes of the Elizabeth River. The data generated from a comprehensive monitoring program will provide the information needed to manage and make important decisions regarding the Elizabeth River. A well designed monitoring program will document long-term trends in environmental quality and should reveal how effective specific programs are at controlling and abating pollution problems.

The initial step in developing a monitoring program is the identification of the goals of the program. Once identified, a statistically valid sampling design can be developed that is aimed at answering specific questions. A monitoring program should also be coordinated with other agencies' programs and requirements. Standardization of sampling and analysis procedures and a stringent quality assurance/quality control (QA/QC) program is required to provide consistent and reliable data. Comparing data generated using various sampling and analysis procedures with varying degrees of QA/QC is difficult, if not entirely impossible.

Too often, data generated for monitoring purposes is never analyzed or reported in a fashion which makes the information useful or available. Thus, the anticipated analyses and report products should be determined during program development and structured toward achieving the goals of the program.

A monitoring program is not an end in itself, rather it should compliment and support the entire Elizabeth River project. There will be careful consideration in allotting the available resources between monitoring and those programs aimed at solving the Elizabeth's complex problems. Monitoring is not intended to act as the buffer which delays decision making when a preponderance of evidence indicates that a problem exists and corrective plans need to be implemented. Monitoring programs are integral components of all the large scale water body projects such as the Chesapeake Bay Program, the National Estuary's Program, and the plan developed for the management of Puget Sound. Monitoring must be viewed as an integral and essential component of any effort to manage and restore the Elizabeth River.

Monitoring does not imply research, although overlap does occur. Research differs from monitoring in its fundamental objective. Research involves intensive investigation or experimentation to discover or interpret new facts. A strategy for developing research activities in the Elizabeth River is presented in the following section.

Goal
Develop a comprehensive monitoring program designed for long term monitoring and assessments of the water, sediment, and biological resources of the Elizabeth River. This program will serve as an indicator of environmental change in order to evaluate the success of restoration strategies, provide a continuing record of the environmental quality of the River, and assist managers and scientists by identifying areas of concern and significant trends.

Strategy
A monitoring committee, chaired by the SWCB, will be established to develop goals and objectives for the monitoring program, review proposals and reports, and evaluate the monitoring program.

Recommendations
The Elizabeth River monitoring committee shall;

M1.1 Host an Elizabeth River monitoring workshop.
M1.2 Develop a list of goals and objectives for the monitoring program.
M1.3 Based on the goals of the program, a statistically valid sampling program will be developed to meet the goals and objectives.
M1.4 Designate roles of various agencies in the program and coordinate the monitoring program with other programs and activities.
M1.5 A data management program, consistent with the program established by OERS, will be implemented.
M1.6 Review data and reports generated from the program.
M1.7 Periodically review the monitoring program and evaluate its success.
M1.8 Prepare biennial summary reports on status and trends for the Elizabeth River. Significant trends which may adversely affect the river, its resources, or the human population will be emphasized.
M1.9 When necessary, redirect the current program or initiate new ones to meet the goals of the program.

RESEARCH

Scientists have been investigating the Elizabeth River, its processes and resources for over two decades and have accumulated a wealth of information, yet significant questions pertaining to the Elizabeth remain unanswered. Funding of research projects has been slashed in the last few years and has reduced the number of research efforts in the Elizabeth River. A concerted effort to identify and prioritize research needs and locate adequate funding will serve to advance our knowledge of the Elizabeth.

With the reduction in funding for research activities, it is essential that a coordinated effort among funding agencies, regulators, and research entities be developed. This will ensure that the highest priority research is funded, while at the same time, communication and coordination among each group will be enhanced.

More often than not, research results are not available in a form or media which are most beneficial to regulators, managers, or the public. It is essential that research results be reported in a fashion which disseminates the information to those groups or individuals which require the information.

Goal
Establish priorities and seek funding for research that will, advance our knowledge of the Elizabeth River, identify the cause and solutions to complex pollution problems, and assist regulators and managers with difficult decisions.

Strategy
A research committee, consisting of authorities in various fields of science, will be established to identify the most critical research requirements for the Elizabeth. The committee will serve as a technical review panel to advise state and federal agencies as to the merit and priority of solicited and unsolicited research proposals. The panels' suggestions will assist funding agencies in allocating the limited research funds that are available.

Recommendations
The research committee shall;

R1.1 Develop a list of long term and short term research needs for the Elizabeth River Basin.
R1.2 Recommend the structure for setting priorities on the identified research projects.
R1.3 Identify the role of State Agencies in funding research projects.
R1.4 Identify and develop potential sources of funding for research in the Elizabeth River.
R1.5 Develop a structure for which research results will be made available to the general public in a manner which is consistent with the overall Elizabeth River Project.

R1.6 Develop a strategy for publishing research results from State Agencies, industry, and other organizations which do not routinely publish research results.

R1.7 Develop a program to present relevant research results to the scientific community, regulators, policy makers, and environmental managers.

LIVING RESOURCES

The living resources of the Elizabeth River have been severely impacted as a result of man's activities. Development has reduced tidal wetlands to mere vestiges along most of the Elizabeth River. Commercial harvesting of shellfish has been prohibited since the early 1900's because of bacterial contamination and high levels of toxic compounds. The shellfish and fish which were historically so abundant, are greatly reduced. Although the Elizabeth River is not "dead", its fate as a viable estuary is uncertain.

The overall Elizabeth River strategy is directed at reducing or eliminating the input of pollutants into the River. This goal must be realized for the living resources to achieve the diversity and abundance that previously occurred in the Elizabeth River. We must understand that this goal will not be achieved in a short time, but may require several years or longer before the Elizabeth River approaches the environmental quality required to support a thriving estuarine community. Monitoring and research projects will identify future programs required to restore the living resources of the Elizabeth River. There are several immediate actions that can be imposed to benefit the living resources of the River, most notable is the identification and preservation of tidal wetlands. Tidal wetlands are an integral part of the estuarine ecosystem and are valuable resources, providing food and shelter for wildlife and fishes and protecting water quality. These qualities are particularly important in the urban environment. Tidal wetlands buffer streams and rivers from pollution by slowing and storing stormwaters and filtering the runoff by trapping nutrients and suspended solids and helping break down toxic compounds. Tidal wetlands also stabilize shorelines, thus helping to prevent erosion. Tidal wetlands are also important areas for their educational, research, and aesthetic value.

A concerted effort to preserve and expand tidal wetlands is a necessary first step in improving the quality of the Elizabeth River. The Virginia Marine Resource Commission is the State agency responsible for managing the State Wetland's Management Program. The program allows local governments to form a citizens board which reviews and makes decisions on permits for wetlands destruction or alteration. The Virginia Marine Resource Commission oversees and provides assistance to local Wetlands Boards and reviews appeals from applicants who are denied permits. The program has been successful in preserving a valuable resource. The scope of the State Wetland Program should be expanded as a first step in improving the environmental quality of the Elizabeth River.

<u>Goal</u>
Insure that important wetlands are identified and preserved and degradation of others are minimized. Additional measures shall be developed that will benefit the living resources of the Elizabeth River.

Strategy
The strategy to achieve this goal is through an inventory of wetlands in the Elizabeth River Basin and designation of critical wetland areas. Critical wetlands will be preserved and mechanisms developed to expand tidal wetlands in other areas. Local Wetlands Boards will have more authority to prevent the destruction of wetlands and direct research into the effectiveness of wetlands as pollution barriers.

Recommendations

W1.1 VIMS shall continue and complete the tidal wetlands inventory for the Elizabeth River Basin.
W1.2 VIMS shall develop criteria for designating critical wetlands.
W1.3 Techniques and mechanisms for preserving and protecting critical wetlands (through purchase, etc.) in the Elizabeth River shall be developed by the Virginia Marine Resource Commission. Assistance will be given to agencies, organizations, or private parties wishing to preserve wetlands.
W1.4 Development of wetlands will be accomplished by mitigation and other mechanisms.
W1.5 The Virginia Marine Resource Commission shall oversee wetlands in the Elizabeth River through the State's Wetlands Management Program.
W1.6 Local Wetland Boards should receive wider authority to protect wetlands.
W1.7 Nontidal wetlands shall be identified and efforts undertaken to preserve them.

LABORATORY SERVICES

Many of the programs involving the Elizabeth River and surrounding waters, including the Chesapeake Bay, require laboratory support to provide accurate and reliable information regarding physical, chemical, and biological parameters. The integrity of this information is of the utmost importance because important and far reaching decisions are often based on results from these various programs.

Existing programs and those developed in this plan provide essential information necessary to understand the complex interactions occurring within the Basin and assess the environmental health of the Elizabeth River. VPDES permittees are required to provide laboratory data indicating the quality of effluent discharges and whether permit limits are being violated. The SWCB's VPDES Toxics Monitoring Program (TMP) requires extensive chemical and biological testing on selected VPDES discharges to determine the toxic nature of the discharge. These programs and those being developed for the Elizabeth River Restoration Strategy will require considerable laboratory services, therefore an evaluation of the available laboratory support is essential to the success of the strategy. Administrators of the Chesapeake Bay Program have realized the importance of quality data in establishing baseline date for the Bay and its importance in determining the effectiveness of current programs. Many existing programs are increasing the emphasis on toxics monitoring (chemical and biological monitoring) which requires sophisticated instrumentation and techniques and highly trained personnel. The capacity to meet the current requirements are already stressed and needs will increase in the near future.

Protocols for chemical and biological testing are not always standardized, and even if they are, individual laboratories can be highly variable in the manner in which they carry out the protocols. Quality assurance/quality control (QA/QC) programs help produce quality data within laboratories and allow comparison of data between laboratories. In many instances, QA/QC programs do not exist or they are highly variable from laboratory to laboratory. Lack of QA/QC results in questionable data which is, in essence, useless. Comprehensive QA/QC programs are necessary to produce accurate, reliable, and comparable data. The EPA's contract lab program has an extensive QA/QC requirements built into its priority pollutant analysis programs and requires a certification process as part of its program. Programs with substantial QA/QC result in higher analytical costs but insures the usefulness of the data, especially when legal actions are taken as a result of the analyses.

Several environmental/regulatory agencies in other states have developed laboratory certification programs to meet the needs of their programs. These laboratory programs vary in scope, and thus the resources necessary to implement them vary. Currently, Virginia only has a certification program for laboratories performing drinking water analyses. The SWCB inspects labs performing routine analyses required by the VPDES program, but nonroutine analyses (chemical and biological) are not covered in the program.

Goal
Insure the accuracy, reliability, comparability, and timeliness of physical, biological, and chemical laboratory tests to support existing and future environmental programs in the Elizabeth River Basin and surrounding waters.

Strategy
To achieve this goal the SWCB will identify present and future laboratory requirements, review current laboratory capabilities, and recommend alternatives to meet these requirements. The SWCB in coordination with other State and Federal agencies will develop a program guidance manual which will detail approved methods for sampling and testing, minimum QA/QC requirements, and data tracking and submittal requirements.

Recommendations

Laboratory support

L1.1 Develop comprehensive list of present and future laboratory requirements; review existing laboratory support, laboratory performance, and priority needs so that resources can be allocated to develop those needs.
L1.2 Allocate resources to develop or expand the State's in-house services.
L1.3 Allocate resources to develop contract services for sampling and analysis.

QA/QC Program

L2.1 State Agencies shall, in coordination with Federal Agencies and research institutions, develop standard protocols for all existing programs and develop criteria for establishing alternate protocols.
L2.2 Standard QA/QC requirements will be developed for all protocols.
L2.3 Develop standardized sample tracking and data submittal requirements.
L2.4 Develop a coordinated data management system.

Laboratory Certification Program

L3.1 Develop a phased program for laboratory certification.
L3.2 Insure adequate laboratory capacity prior to requiring the use of certified labs.
L3.3 All physical, chemical, and biological sampling and testing will be performed by certified laboratories.

URBAN GROWTH AND DEVELOPMENT

The Elizabeth River has served as the focal point for military, industrial, and commercial growth in the Hampton Roads area. The proximity of the port to the Chesapeake Bay and the Atlantic Ocean and the vast resources of nearby inland regions have contributed to make it an important maritime port.

The region, from its inception, grew and prospered and led to the establishment of the future Cities of Norfolk and Portsmouth, and eventually Chesapeake and Virginia Beach along the River's shore. The strategic location of the Elizabeth River has encouraged military, industrial, and commercial development within the Basin. The population on the Basin has grown in accordance with the development of the Basin.

The SVPDC developed a population forecast for the Elizabeth River as part of the "Hampton Roads Water Quality Management Plan Update" in 1983. The projection includes the five major sub-basins in the Elizabeth River and includes 1970 population figures and estimates for the years 2000 and 2005. The projections indicate that the bulk of the projected 20 percent increase will occur in the upper reaches of the Eastern, Southern, and Western Branches in the form of low density residential development.

Waterfront development was cited as a major issue in the SWCB's 1984 report "Background and Problem Assessment for the Elizabeth River". The concern centered around the compatibility of future waterfront development with existing land use activities. At the time the report was produced, the City of Norfolk had developed its waterfront festival place, Waterside, and shortly thereafter Portsmouth developed Portside. This issue, waterfront development, has been expanded to include urban growth and development, because of the water quality implications.

The SVPDC projected that a significant portion of the Basin will remain undeveloped or in agricultural use. Low density residential and light industry will account for 20 and 15 percent of the Basin, respectively. The remaining land use categories account for 10 percent or less of the remaining basin acreage. It is notable that although only 2 percent of the Basin is occupied by heavy industry, most of it is located on or near the waterfront in the Eastern or Southern Branches. This is particularly important because these industries are major generators, handlers, and transporters of hazardous waste. These population and land use projections indicate a potential for a substantial increase in land utilization by the year 2000 which can be expected to significantly impact water quality through nonpoint source pollution contributions.

Traditionally, control of land use and development in Virginia has been left to local governments. Local jurisdictions use a variety of mechanisms, including comprehensive planning, zoning, and subdivision regulations to control development. Implementation of the SWCB's BMP guidelines and the ESCL are additional mechanisms which are used by local governments to reduce nonpoint source pollution resulting from land development. Although none of the cities in the Elizabeth River Basin have adopted water quality as a formal goal, there are means by which local governments can protect water quality. Many of the comprehensive plans developed by the Basin cities have programs which support Federal and State water quality goals, but many other programs have the potential to conflict with water quality goals. For example, a draft comprehensive plan for the City of Chesapeake encourages the development of the deep water sections of the upper reaches of the Southern Branch. These conflicts can be resolved by cities modifying existing programs or adopting alternative plans which are supportive of water quality goals.

Through the Coastal Zone Management Program, the SVPDC is currently developing recommendations, in cooperation with state and local authorities, to enhance land development regulations and policies that will benefit the environmental quality of the Elizabeth River.

At the State level, the General Assembly enacted legislation to create a new state agency (CLAB) that would develop land use regulations and provide guidance to localities along the Chesapeake Bay. The agency will assist Virginia with protecting and restoring the Chesapeake Bay by providing for a balance between the rapid development along the Bay and the protection of the Bay and its living resources.

Goal

Insure that environmental quality is an integral part of the development of the Elizabeth River Basin.

Strategy

Local governments and regional planning agencies will develop policies and procedures that will minimize adverse effects resulting from development within the Basin.

State agencies will assist local entities and provide technical assistance.

Regulatory measures will be developed to control nonpoint source pollution.

Environmentally sound development of the Basin, which benefits the region, shall be encouraged.

Recommendations

Institutional and Policy Recommendations

U1.1 The NPS control strategy developed in the 1983 HRWQMP update should be the starting point for developing a Basinwide strategy for land use and development.
U1.2 Cities should adopt water quality as a formal goal.
U1.3 Adopted water quality goals should be part of the cities' comprehensive plan.
U1.4 Water quality, as an adopted plan goal is to be incorporated into zoning, subdivision regulation and other land use regulations.
U1.5 Incorporate the Elizabeth River Restoration Program with other programs to achieve mutual benefits.
U1.6 Continue public education programs.

Regulatory Measures

U2.1 Enforcement of ESC ordinances should be increased.
U2.2 BMPs required on all new developments, especially those dealing with hazardous wastes. Use existing regulations (i.e. zoning) to implement comprehensive package of controls.
U2.3 Enforce Urban BMPs as a pretreatment strategy for stormwater.

Addition Elements

U3.1 Provide more public access to the river.
U3.2 Ensure that river and shoreline are kept clean.
U3.3 Develop low impact areas for the public benefit.
U3.4 Protect unique habitats and environmentally sensitive areas (See Living Resources).

EDUCATION AND PUBLIC INVOLVEMENT

In order to stimulate involvement by the public and private sector it is necessary to develop an understanding of the nature of the Elizabeth River, its pollution problems, and the polices and programs required to restore the River. A successful restoration program will require an ongoing commitment from an informed and involved public. In addition, those agencies developing and carrying out the programs on the River must be responsive to the concerns and desires of the public. Significant actions should not be taken without consulting interested and affected parties.

Education and involvement are the best means to control pollution which results from the acts of individuals (i.e. boat pollution, trash, lawn fertilizers).

The Chesapeake Bay Agreement of 1987 included public education and participation as a major element because it was realized that meeting the needs of the public is a driving force behind the protection and restoration of the Bay. A spirit of openness among all concerned parties benefits the effort. Public education and involvement must be recongnized as an integral part of the Elizabeth Restoration effort.

Goal
To inform the public about the Elizabeth River, efforts to restore it, and encourage public participation in these efforts.

Strategy
Provide increased opportunities to inform the public about the Elizabeth River and programs initiated to control pollution and restore the system. Provide opportunities for the public to participate in decision-making, developing programs, and participating in Restoration efforts.

Recommendations
E1.1 Provide timely information to the public.
E1.2 Assure that the public has ample opportunities to understand official programs and proposed actions.
E1.3 Assure government responsiveness to public concerns.
E1.4 Enhance education and public awareness programs.
E1.5 Provide opportunities to students to learn about the Elizabeth River and its processes.
E1.6 Promote opportunities for citizen participation in Elizabeth River Restoration projects.

APPENDIX A

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APPENDIX B

ACRONYMS

ACOE -Army Corps of Engineers
AMRL -Applied Marine Research Laboratory
BMP -Best Management Practices
BOD -Biochemical Oxygen Demand
CLAB -Chesapeake Local Assistance Board
CWA -Clean Water Act
CZMA -Coastal Zone Management Act
DMR -Discharge Monitoring Report
DO -Dissloved Oxygen
DSWC -Division of Soil and Water Conservation
DWM -Department of Waste Management
EIS -Environmental Impact Statement
EPA -U. S. Environmental Protection Agency
HRSD -Hampton Roads Sanitation District
HRWQA -Hampton Roads Water Quality Authority
HRWQMP-Hampton Roads Water Quality Management Plan
MGD -Millions of Gallons Per Day
NOV -Notice of Violation
NPDES -National Pollution Discharge Elimination System
PAH -Polynuclear Aromatic Hydrcarbons
POTW -Publicly-owned Treatment Works
PPM -Parts Per Million
RSO -Raw Sewage Overflow
SDH -Virginia State Department of Health
SPCC -Spill Prevention Control and Countermeasures
SPSA -Southeastern Public Service Authority
STP -Sewage Treatment Plant
SVPDC -Southeastern Virginia Planning District Commission
SWCB -Virginia State Water Control Board
TMP -Toxicity Management Program
TRE -Toxicity Reduction Evaluation
TSS -Total Suspended Solids
USCG -United States Coast Guard
USN -U.S. Navy
VCOE -Virginia Council on the Environment
VDOT -Virginia Department of Transportation
VIMS -Virginia Institute of Marine Science
VIP -Virginia Initiative Plant
VMRC -Virginia Marine Resources Commission
VPA -Virginia Pollution Abatement (permit)
VPDES -Virginia Pollution Discharge Elimination System
VWA -Virginia Wetlands Act